The August-September-October 2011 Outlook for Colorado, And a Look at this Summer's Monsoon

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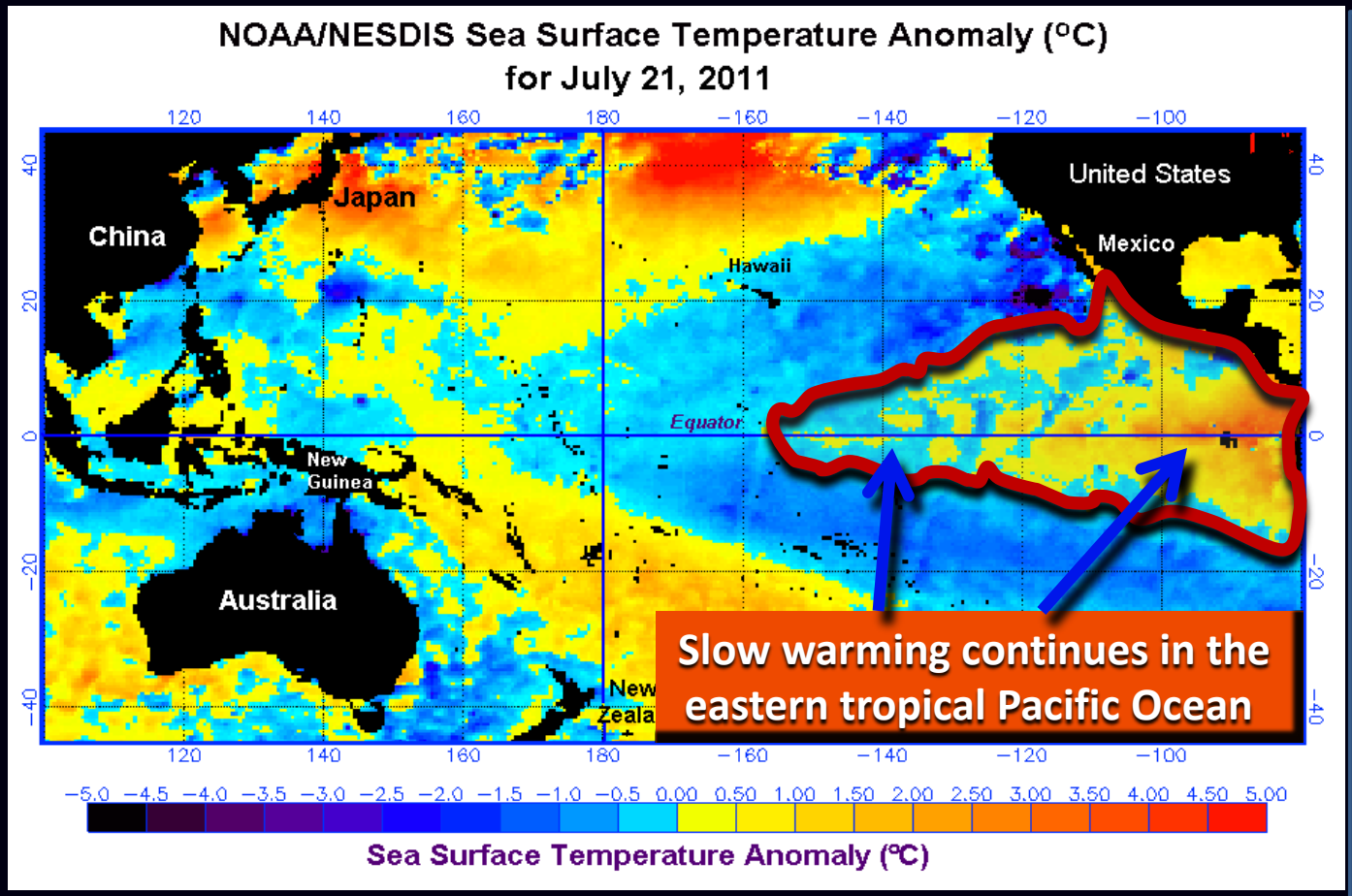
Topics Covered

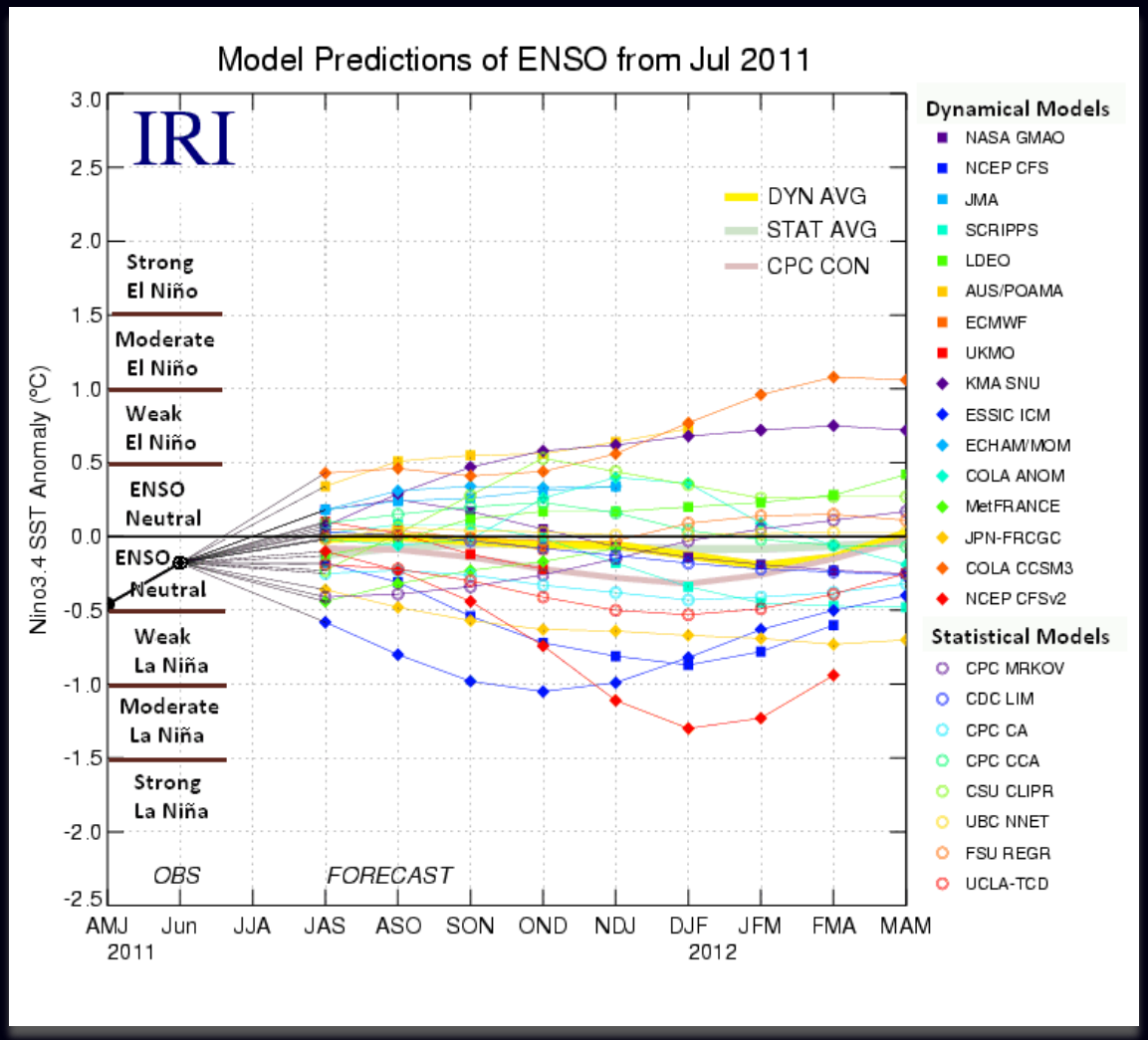
- The latest status on ENSO (El Nino/Southern Oscillation) – and the forecast for ENSO for the next 12 months
- Precipitation, temperature and drought conditions across Colorado during the 90-day period ending July 24, 2011
- The Southwest Monsoon - Its recent impact on the Front Range and the rest of Colorado and what we expect from the monsoon for the rest of the summer
- Three major wind, pressure and thunderstorm distribution patterns most often observed with the summer monsoon
- The perceived impact of the summer monsoon on precipitation, temperature and drought conditions across Colorado during the 30-day period ending July 24, 2011
- The latest Colorado drought conditions and outlook
- Temperature and precipitation outlooks and historical composites for Colorado for the period August, September and October of 2011

La Niña Is No More



In recent weeks, sea surface temperature (SST) departures from average in the tropical Pacific Ocean have continued to shrink, except off of the northwest coast of South America (center right side of this map). It is only in this region of the tropical Pacific that positive SST anomalies have steadily increased. Otherwise, as of mid-July, SSTAs along the Equator generally range from -0.5 to 0.5 deg C, indicative of **ENSO-neutral conditions.**

Model Predictions for El Niño/Southern Oscillation (ENSO) Through March-April-May of 2012

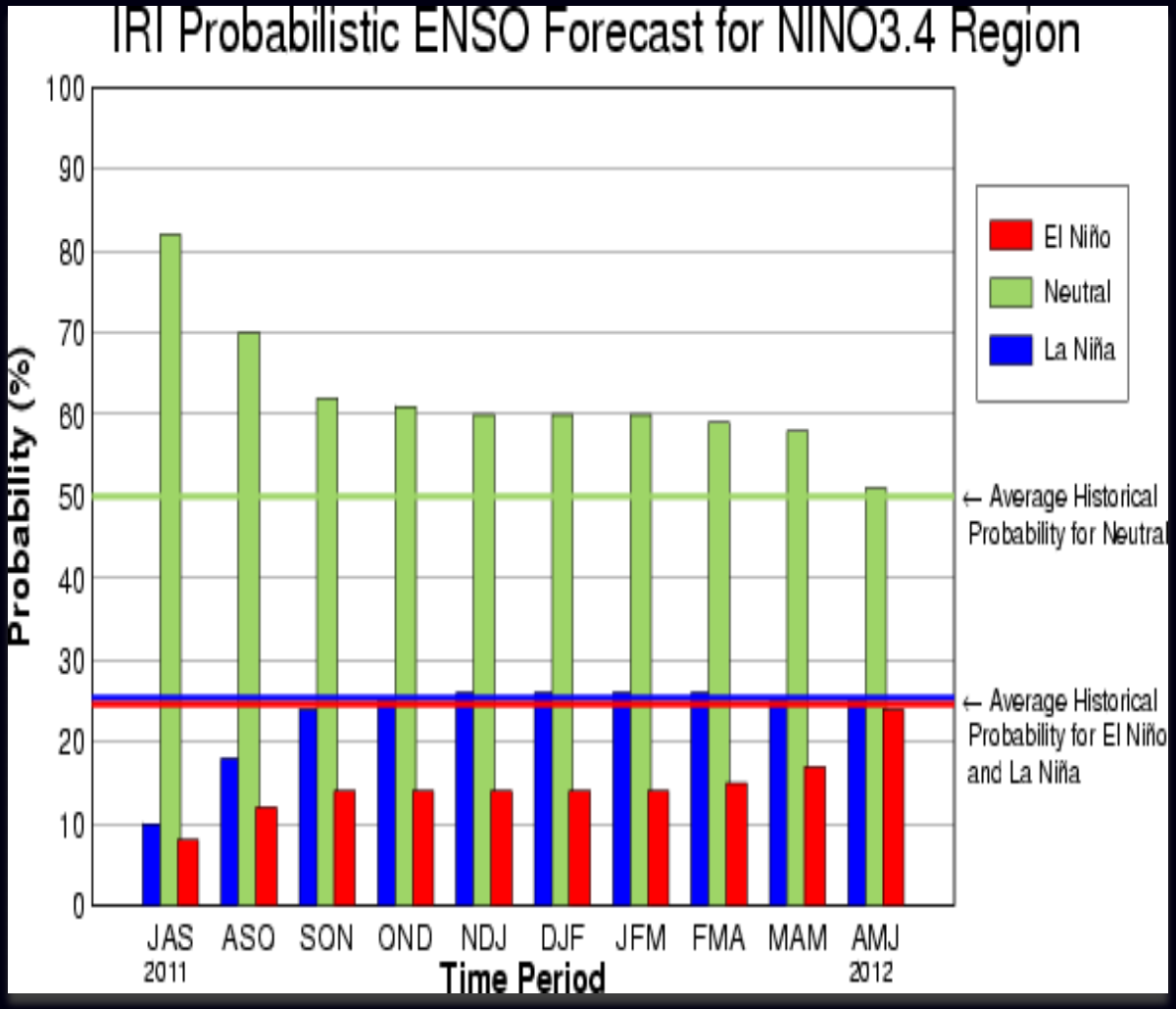


Source: International Research Institute for Climate and Society (IRI) – Updated 7/21/11

Since the demise of La Niña last May, ENSO-neutral oceanic conditions have prevailed across the tropical Pacific Ocean.

Based on observational trends and a majority of the dynamical and statistical ENSO models, the current outlook is for a continuation of ENSO-neutral conditions in the tropical Pacific Ocean through the winter season of 2011-2012.

However, the status of ENSO beyond this summer remains uncertain due to lower model forecast skill out that far, particularly at this time of year. Still some models predict a weak El Niño and a few others a weak La Niña by this fall.



The probabilistic forecast from IRI indicates at least a 50 percent probability that we will see ENSO-neutral conditions this fall and winter.

The latest forecast also indicates a slightly higher chance for La Niña conditions over El Niño conditions later this year.

Source: International Research Institute for Climate and Society (IRI) – Updated 7/21/11

Oceanic Niño Index - ONI

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.6	-1.4	-1.0	-0.8	-0.6	-0.5	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7
2001	-0.6	-0.5	-0.4	-0.2	-0.1	0.1	0.2	0.2	0.1	0	-0.1	-0.1
2002	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.1	1.3	1.5	1.4
2003	1.2	0.9	0.5	0.1	-0.1	0.1	0.4	0.5	0.6	0.5	0.6	0.4
2004	0.4	0.3	0.2	0.2	0.3	0.5	0.7	0.8	0.9	0.8	0.8	0.8
2005	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.2	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.1	0.1	0.2	0.3	0.5	0.6	0.9	1.1	1.1
2007	0.8	0.4	0.1	-0.1	-0.1	-0.1	-0.1	-0.4	-0.7	-1.0	-1.1	-1.3
2008	-1.4	-1.4	-1.1	-0.8	-0.6	-0.4	-0.1	0	0	0	-0.3	-0.6
2009	-0.8	-0.7	-0.5	-0.1	0.2	0.6	0.7	0.8	0.9	1.2	1.5	1.8
2010	1.7	1.5	1.2	0.8	0.3	-0.2	-0.6	-1.0	-1.3	-1.4	-1.4	-1.4
2011	-1.3	-1.2	-0.9	-0.6	-0.2							

Latest ONI

El Niños (warm phase events): ONI of +0.5 and higher (red numbers)

La Niñas (cold phase events): ONI of -0.5 and lower (blue numbers)

ENSO-Neutral (near average conditions): ONI below 0.5 and above -0.5 (black numbers)

An ONI of -0.2 is an indication of ENSO-neutral conditions in the Niño 3.4 region during the three-month climate season of April-May-June of 2011.

NOAA/CPC July 21 2011

The ONI is based on sea surface temperature (SST) departures from average in the Niño 3.4 region of the eastern tropical Pacific and is a principal measure for monitoring, assessing and predicting ENSO.

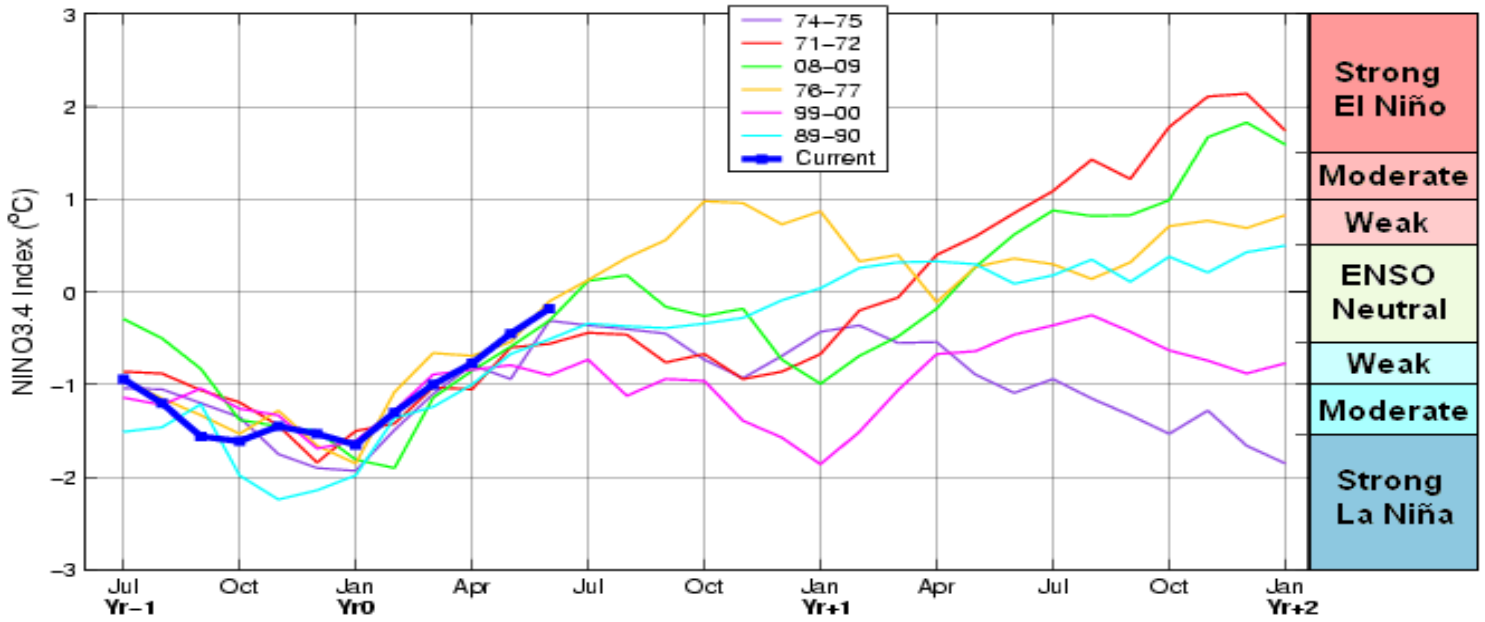
ONI is defined as the three-month running-mean SST departures in the Niño 3.4 region.

ONI is used to place current ENSO and non-ENSO events into a historical perspective.

NOAA's operational definitions of El Niño and La Niña are keyed to the ONI index.

A Comparison of the Seven Strongest La Niña Events Since 1970

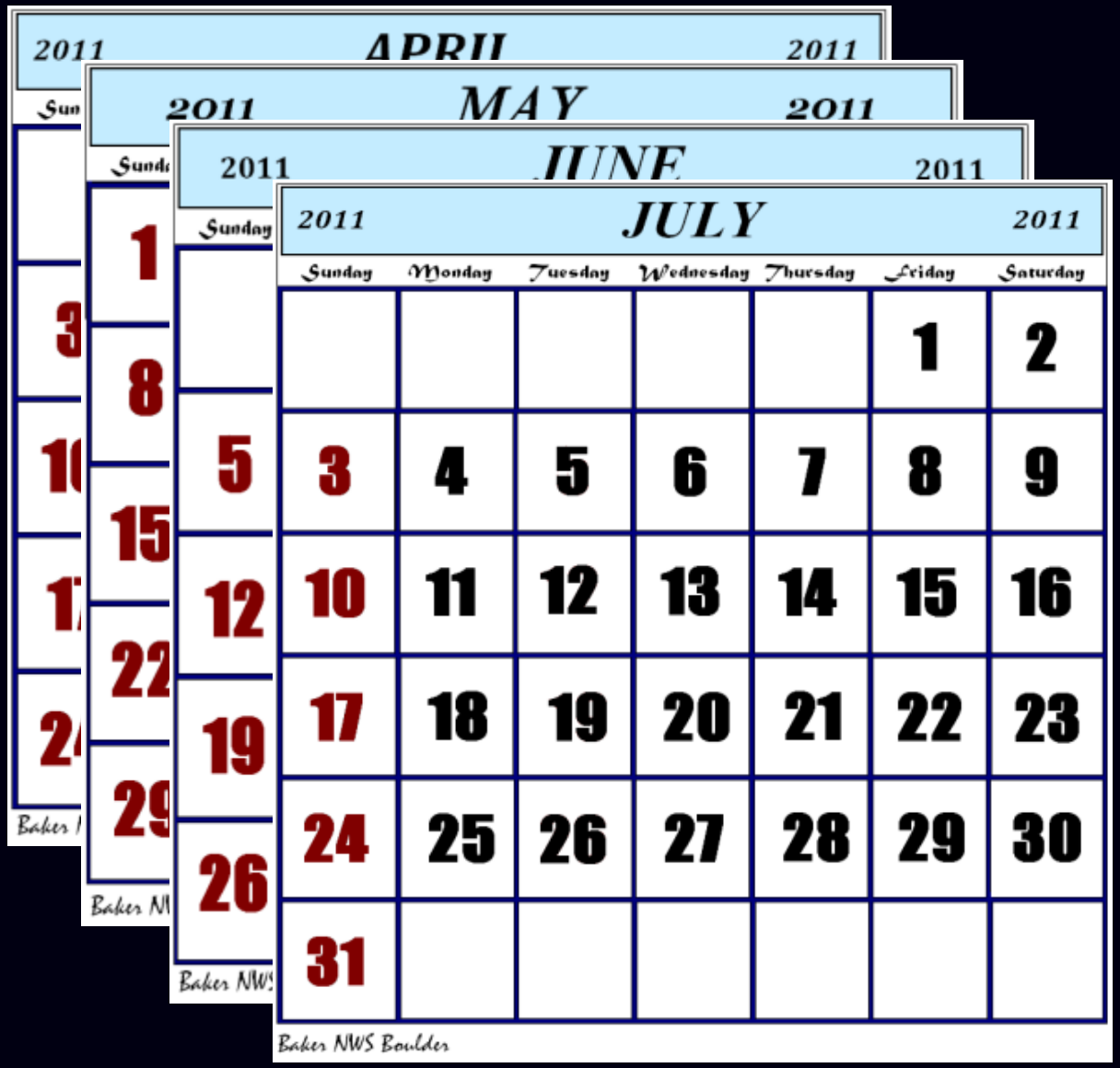
Current vs. Past Niño3.4 Indices (°C)



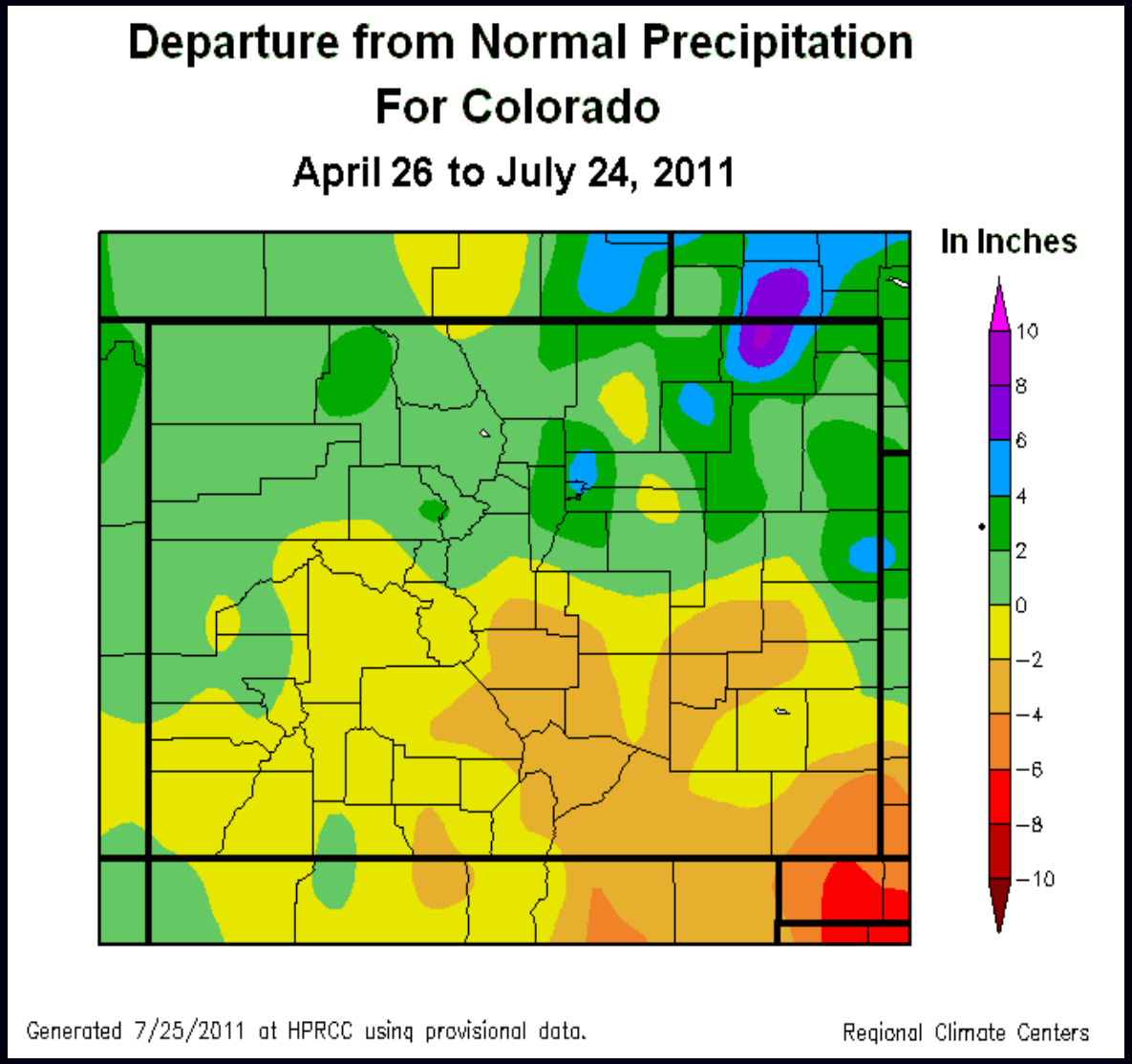
Source: The International Research Institute for Climate and Society -IRI - July 2011

Above is a comparison of current and past Niño 3.4 indices for the seven strongest La Niña events since 1970. All seven events were classified as weak by April following the winter season of greatest intensity, and a majority of them ended by the start of summer. The current Niño 3.4 index (thick blue line) has continued to weaken at a pace similar to that observed following the 1976-77 and 2008-09 La Niñas.

Except for the strong La Niña events of 1999-2000 and 2010-2011, Niño 3.4 indices for the other five events indicated ENSO-neutral conditions during the following summer. Not until the following autumn did it become apparent what direction these indices would take for the next winter. A majority of these indices stayed within the range of 0 to -1, indicating neutral to weak La Niña conditions.

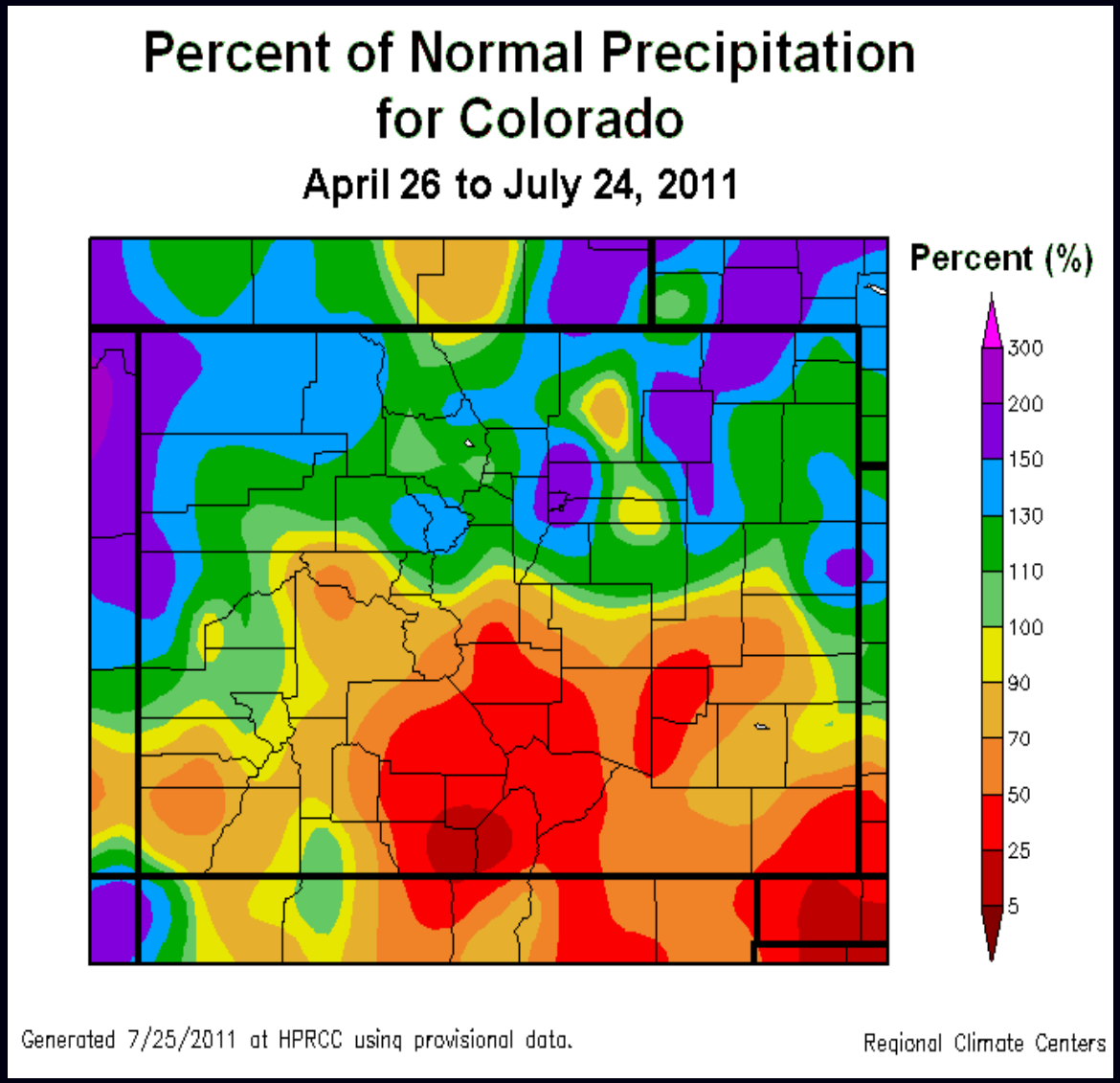


Precipitation, and Drought Conditions Across Colorado from Mid-April to Mid-July 2011



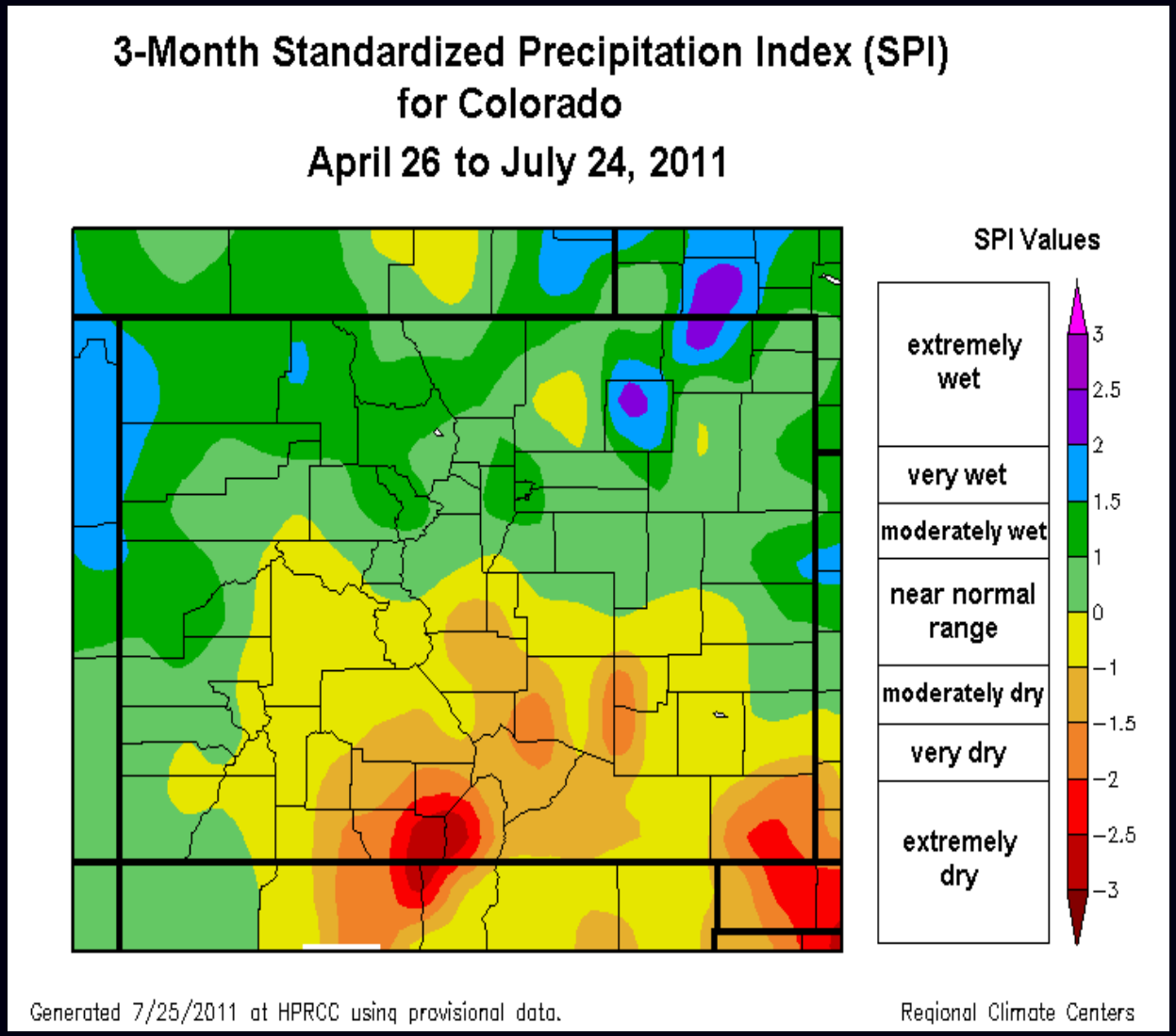
Precipitation departures from normal varied widely across Colorado during the 90-day period ending July 24, 2011. Departures ranged from around 8 inches above normal in the northeast corner of Colorado to around 6 inches below normal in the southeast corner of the state.

In general, precipitation was above normal across northern and western Colorado, including along the Front Range, and below normal across south central and southeast Colorado.



From another perspective, precipitation totals during the same period ranged from 100 to 200 percent of normal across northern and western Colorado, with close to 300 percent of normal in the far northeast corner of the state.

South central and southeast Colorado continued to experience large precipitation deficits. Ninety day totals ranged from 15 to 90 percent of normal. Once again, areas with the least rainfall include the San Luis Valley in south central Colorado and lower portions of Arkansas River Basin in southeast Colorado.

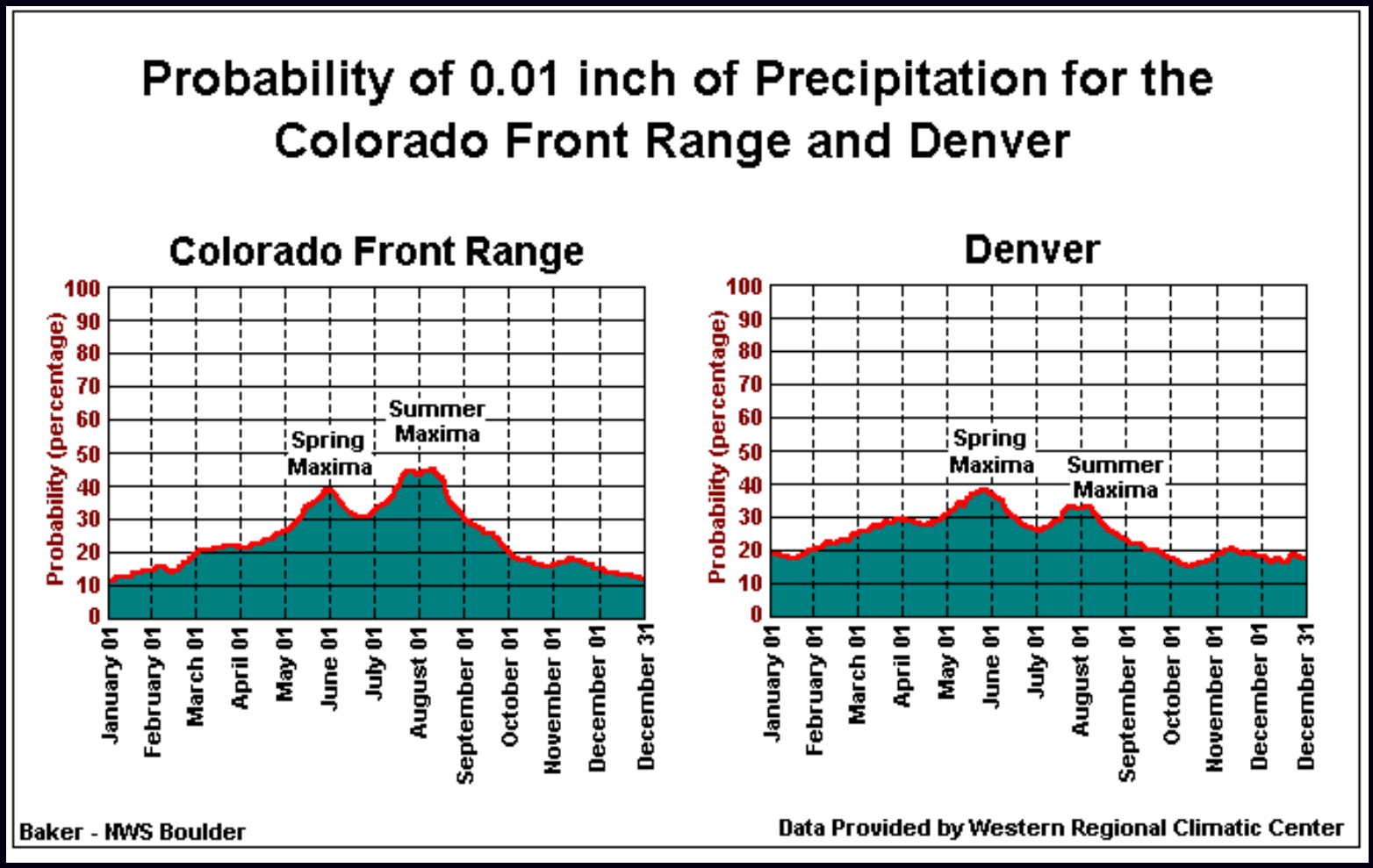


During this same three month period, the Standardized Precipitation Index (SPI) continued to indicate moderately wet conditions across northwest Colorado and extremely wet conditions near the Nebraska border.

Otherwise, near normal to extremely dry conditions prevailed across south central and southeast Colorado.

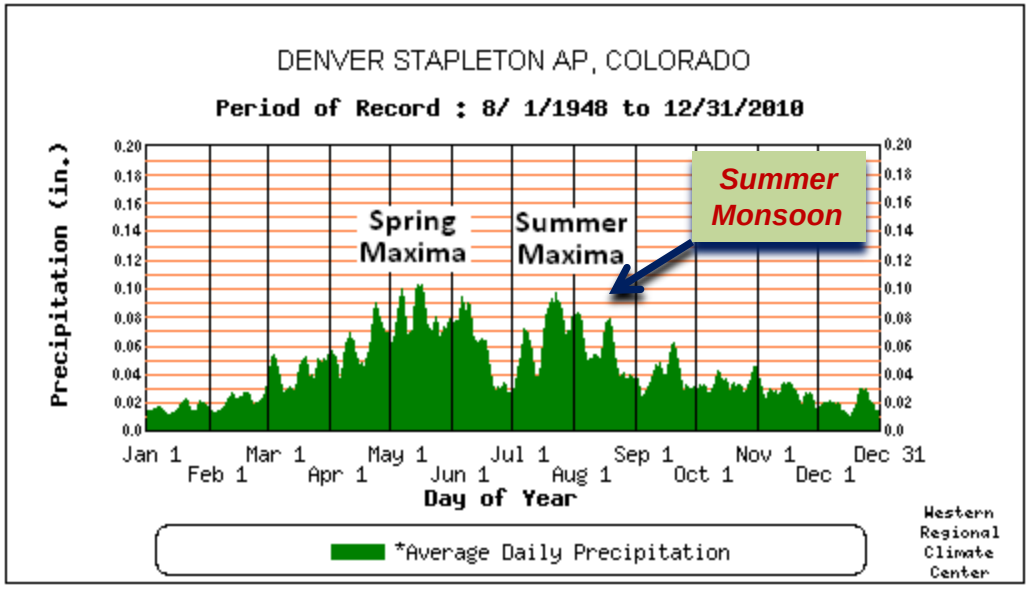
The SPI was developed to monitor potential short term agricultural and long-term hydrological drought conditions. The SPI is a probability index that considers only precipitation.


The
Southwest Monsoon –
Its Recent Impact on the Front Range
and the Rest of Colorado and
What We May Expect
For the Rest of this Summer
Baker - National Weather Service, Boulder, Co

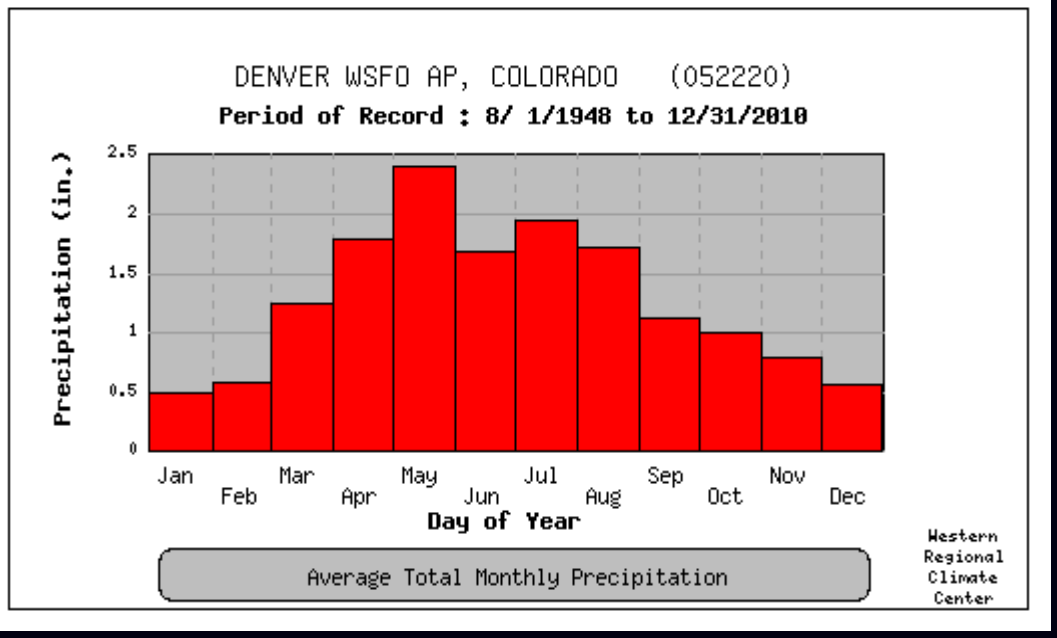


In general, there are two seasonal precipitation maxima or peaks in and along the Front Range of northern Colorado.

The probability of measurable precipitation (at least 0.01 inch) is greatest during the summer for the Front Range mountains and greatest in the spring for the Denver metropolitan area.



* 5 day running average of all daily precipitation recorded for the day of the year. The day of interest is centered in the running average.

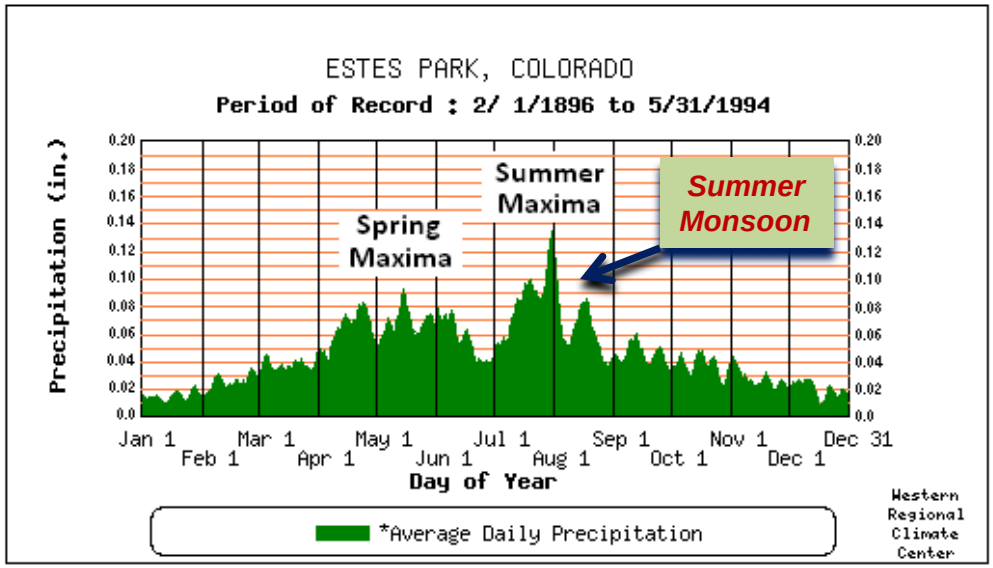


For the Denver Metro Area…

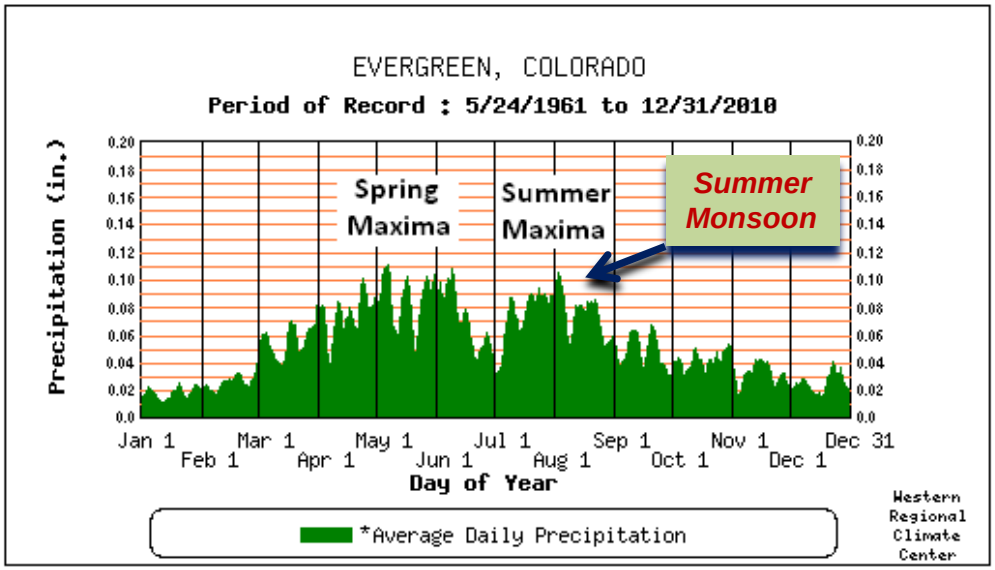
The first seasonal precipitation maxima, or peak, occurs on average during the second and third weeks in May.

The second precipitation peak occurs, on average, during the third and fourth weeks of July. This second maxima coincides with a period of enhanced thunderstorm activity referred to by many as the ***summer monsoon***.

Monthly precipitation totals for Denver are greatest, on average, during May and July. However, the chance for heavy rainfall causing ***flash flooding*** is historically greater in July and early August during the summer monsoon when storm motions are slower and precipitable water values (total atmospheric moisture) are much greater.



* 5 day running average of all daily precipitation recorded for the day of the year. The day of interest is centered in the running average.



* 5 day running average of all daily precipitation recorded for the day of the year. The day of interest is centered in the running average.

For the Front Range locations of Estes Park and Evergreen…

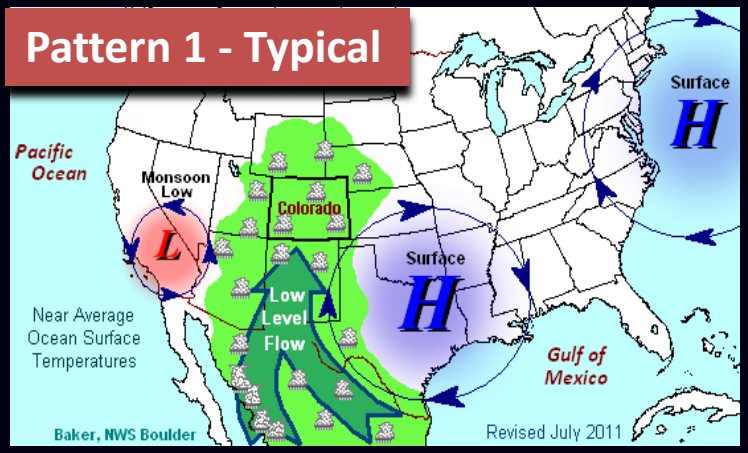
The first annual precipitation maxima occurs on average the second week of May.

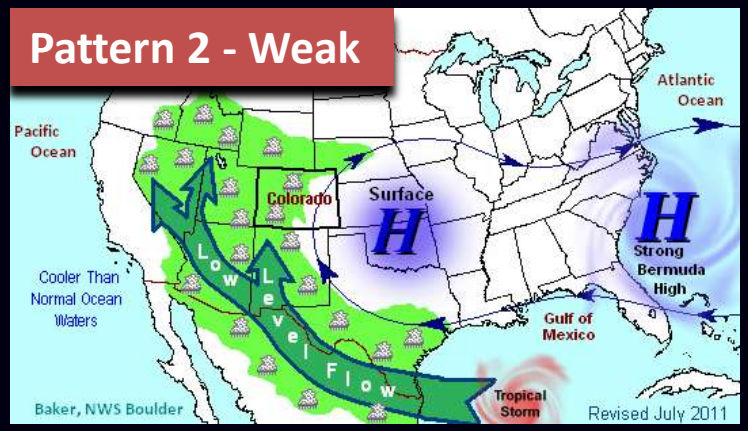
A second annual peak in precipitation occurs, on average, the last week of July. Here, too, this mid-summer spike in precipitation is a manifestation of the ***summer monsoon***.

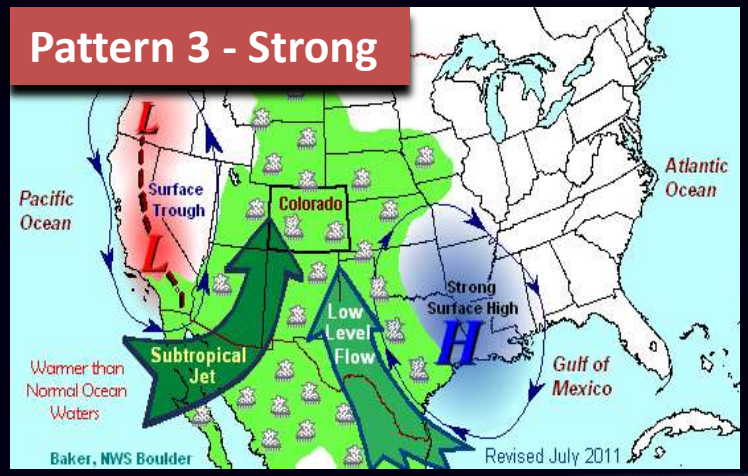
Average daily precipitation is slightly greater during the spring in Evergreen and greater during the summer monsoon in Estes Park. However, the flash flood risk tends to be greater during July and August at both locations.

The summer monsoon in Denver and along the Front Range in northern Colorado begins about July 14th and ends about August 8th. These dates are based on the last 60 years of precipitation data recorded at several observation sites in and along the Front Range. These dates do not take into account the different phases of ENSO (El Niño, La Niña, and ENSO-neutral.)

The American Southwest Monsoon – Three Common Flow Patterns







Monsoon - is derived from the Arabic word “mausim”, meaning *season*. In meteorology, the name commonly refers to a *seasonal wind*.

The American southwest monsoon hardly compares to the greatest monsoon on the planet, the southwest monsoon in India that produces very heavy to torrential rains across the Indian peninsula and much of southeast Asia during the summer and fall.

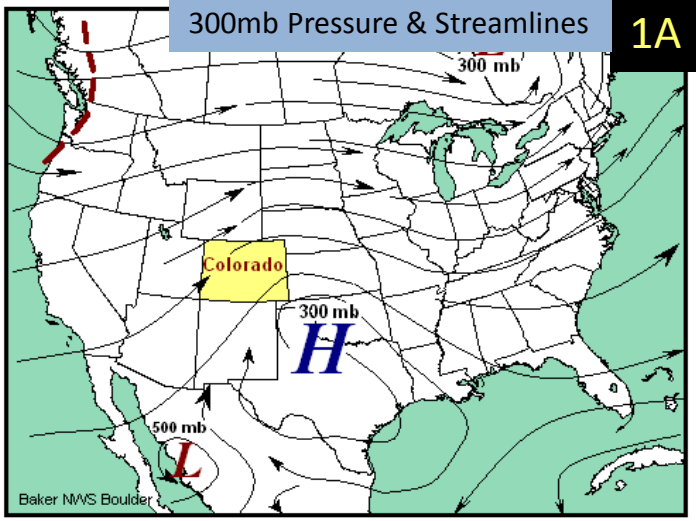
Across the southwestern U.S., strong solar heating during the spring and early summer produces an extensive wind and pressure pattern that transports moist and unstable air northward from subtropical and tropical regions such as the Gulf of Mexico and the very warm waters off the southwest coast of Mexico during July and August.

The American monsoon can take many different trajectories. Its start time and longevity varies widely from year-to-year. Some of this variation can be attributed to different phases of ENSO. The following slides depict three major wind, pressure and thunderstorm distribution patterns associated with American southwest monsoon. Which of these patterns have we seen thus far this summer and what pattern(s) could we still see in the weeks to come will be discussed.

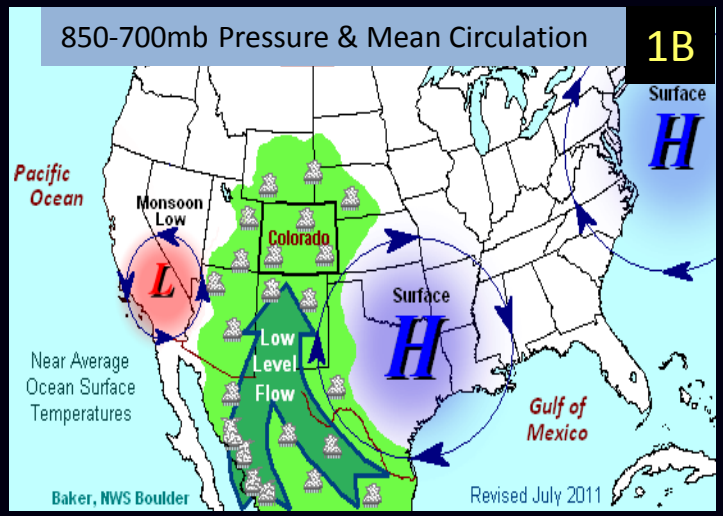
Typical Summer Monsoon Pattern for Colorado

Pattern 1

300mb Pressure & Streamlines 1A



850-700mb Pressure & Mean Circulation 1B

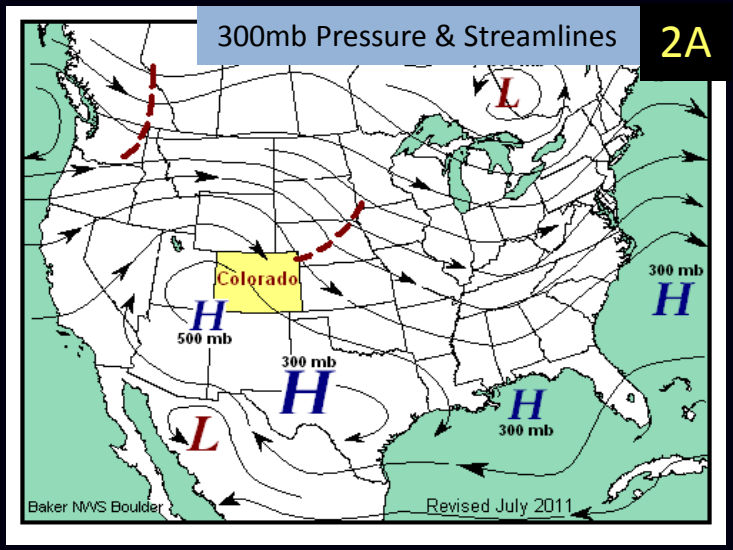


This most common monsoon pattern can appear for a few days to a couple weeks at a time from late June through the middle of August. A strong and hot upper level ridge of high pressure is positioned over the central and southern Great Plains of the U.S. Winds over Colorado, roughly above 10,000 feet ASL, will generally be light in speed from a southwesterly direction (refer to panel 1A).

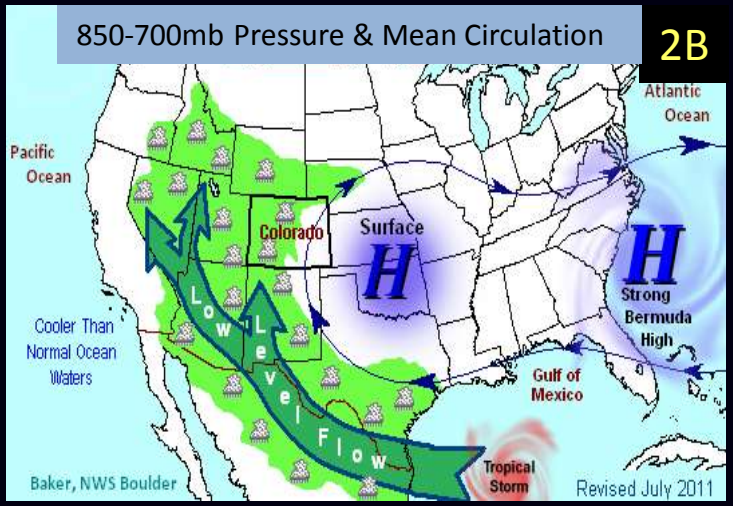
Roughly below 10,000 feet ASL (refer to panel 1B), the prevailing flow across Colorado will generally be southerly in direction. The combined circulation around a strong, often stationary high pressure in the Ark-la-tex-oma region, and a cut-off or heat low (referred to by researchers as the monsoon low) in southern California or western Arizona funnels moisture laden subtropical air of maritime origin northward over eastern Arizona and New Mexico usually by the latter half of June. This monsoon flow, or conveyor belt of moisture, will then continue to spread northward over eastern Utah, Colorado and southern Wyoming during July and early August. Its arrival is often marked by a sudden increase in thunderstorms, noticeably higher dew point temperatures and relative humidity, and in some areas warmer nighttime temperatures. **This summer pattern is more likely to appear during ENSO-neutral and weak ENSO conditions.**

Pattern 2

Weak Summer Monsoon Pattern for Colorado



This next monsoon pattern is not as common as pattern 1. In this pattern, the strong upper level high pressure ridge normally over the Great Plains during much of the summer will be displaced farther west over the Rocky Mountains and/or Great Basin regions (refer to panel 2A.) This westward shift in the upper ridge coincides with a similar westward migration of a stronger than normal Bermuda high that will park over the southeastern United States for much of the summer and possibly early fall.
This westward shift and a northwestward tilt in the upper level ridge causes the monsoon moisture plume to deflect northwestward away from Colorado and more over the Great Basin, possibly as far north as Idaho and eastern Oregon (refer to panel 2B). This particular monsoon pattern can persist for a few days to around a week at a time.

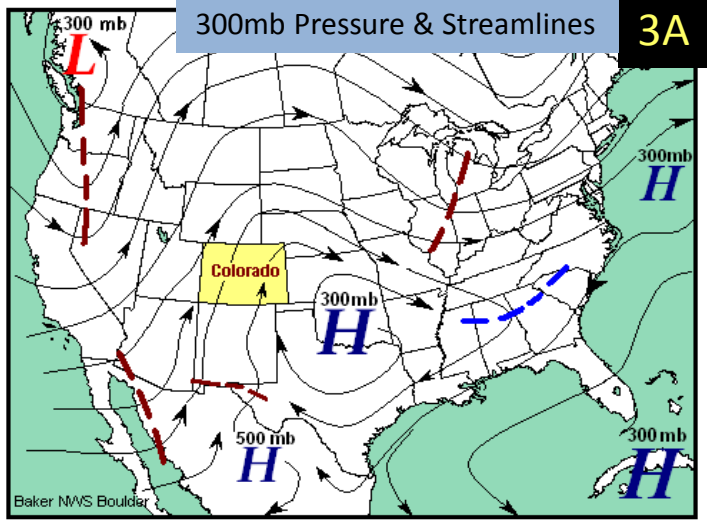


Under this pattern, eastern Colorado generally remains dry and unseasonably warm with the occasional late day thunderstorm drifting off the mountains. Whereas, western Colorado may feel some effect from this redirected moisture flow, particularly if the remnants of a tropical storm are carried along by this flow and passes over the Four Corners region. An active tropical storm season in the Gulf of Mexico (commonly associated with La Niña conditions) can keep this monsoon pattern in place well into September.

Pattern 3

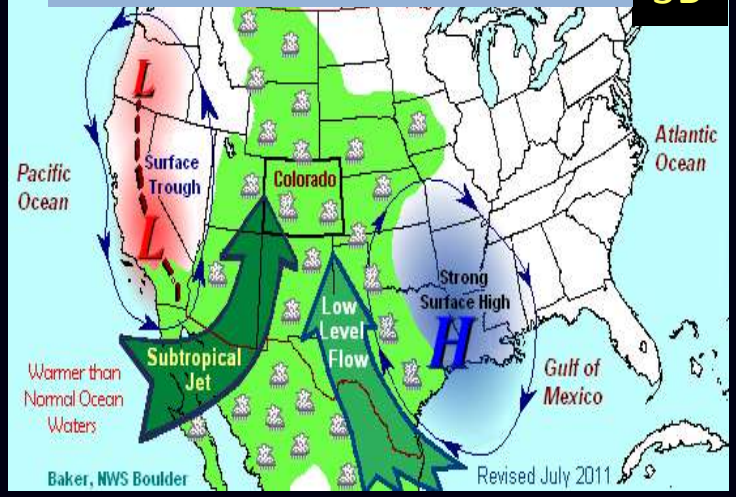
Strong Summer Monsoon Pattern for Colorado

300mb Pressure & Streamlines 3A



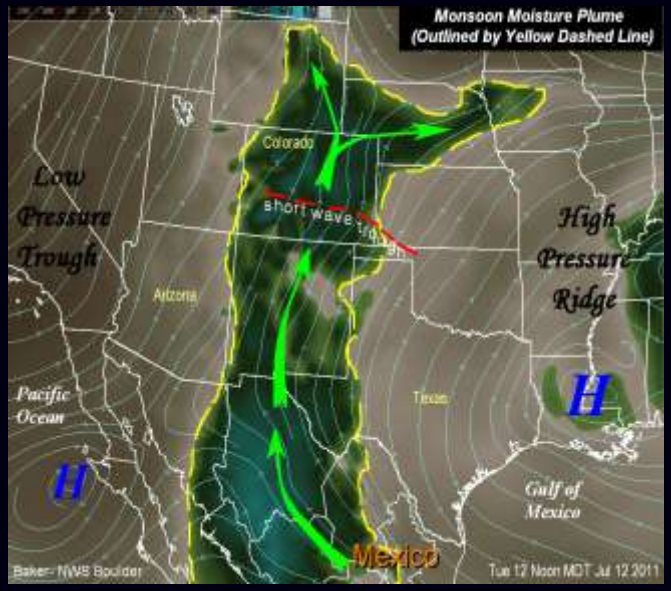
Pattern 3 is similar, in some respects, to the typical monsoon pattern (1) described earlier. A well pronounced upper level high pressure ridge will be located over the central U.S. and Canada where it can remain for weeks at a time, centered around a strong and hot high pressure over the southern Great Plains (see panel 3A). Concurrently, an unseasonably strong upper level low pressure trough will be positioned over the west coast. The mean upper level flow over Colorado is predominantly south-southwesterly in direction.

850-700mb Pressure & Mean Circulation 3B

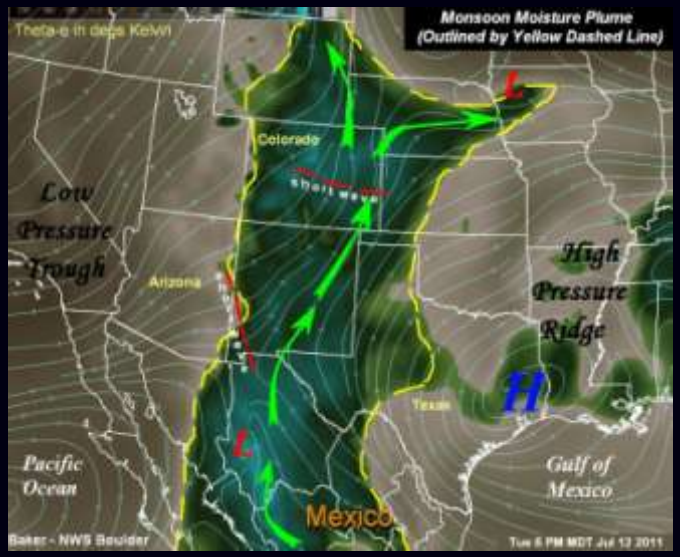


In the lower atmosphere (depicted in 3B), the combined circulation around a strong surface high in the vicinity of the lower Mississippi River Valley and a relatively strong low pressure trough along the Sierra Nevada Mountains in California channels waves of moisture laden subtropical air northward over the lower deserts of the southwest and up along the spine of the Rocky Mountains. What makes this pattern different from pattern 1 is the additional moisture transported up from the tropics by a subtropical jet stream located about 10,000 to 15,000 ft above the ground. This conduit to the tropics can significantly enhance thunderstorm development across the region and the likelihood for very heavy rainfall resulting in flash flooding along and east of the Colorado Front Range. This summer pattern is more likely to appear prior to the start of a moderate to strong El Niño event.

6 PM MDT Monday July 11, 2011



12 Noon MDT Monday July 12, 2011



6 PM MDT Tuesday July 12, 2011

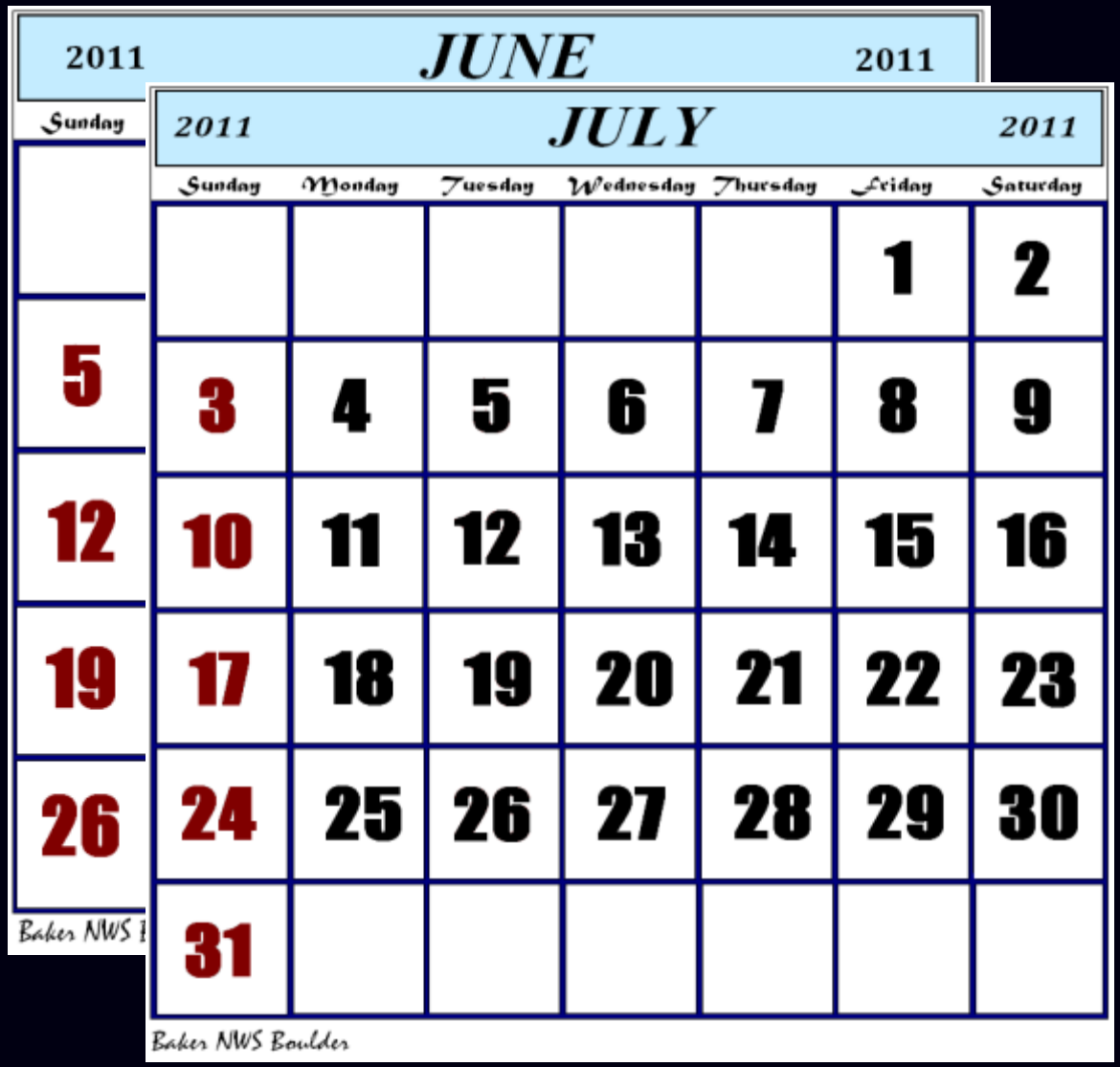
6 AM MDT Wednesday July 13, 2011

Shown in this 4-panel series is a forecast model presentation of initial 5000-18,000 feet ASL moisture and wind streamline fields for late on July 11th through early July 13, 2011.

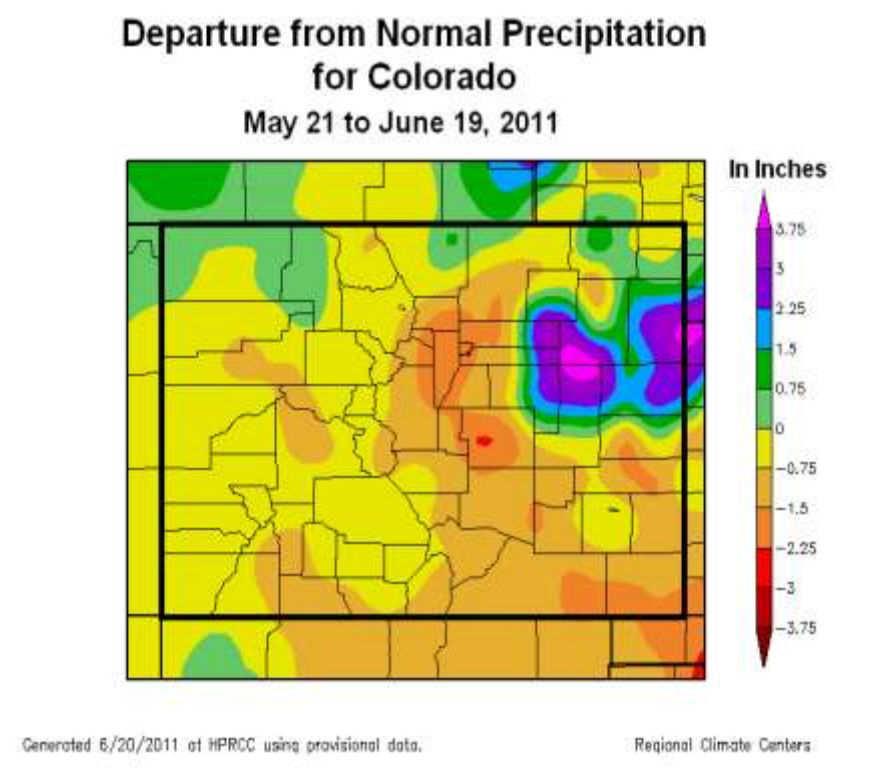
During this period, some of the heaviest rainfall fell on the Denver area, with the greatest rainfall occurring at Denver International Airport on the 13th.

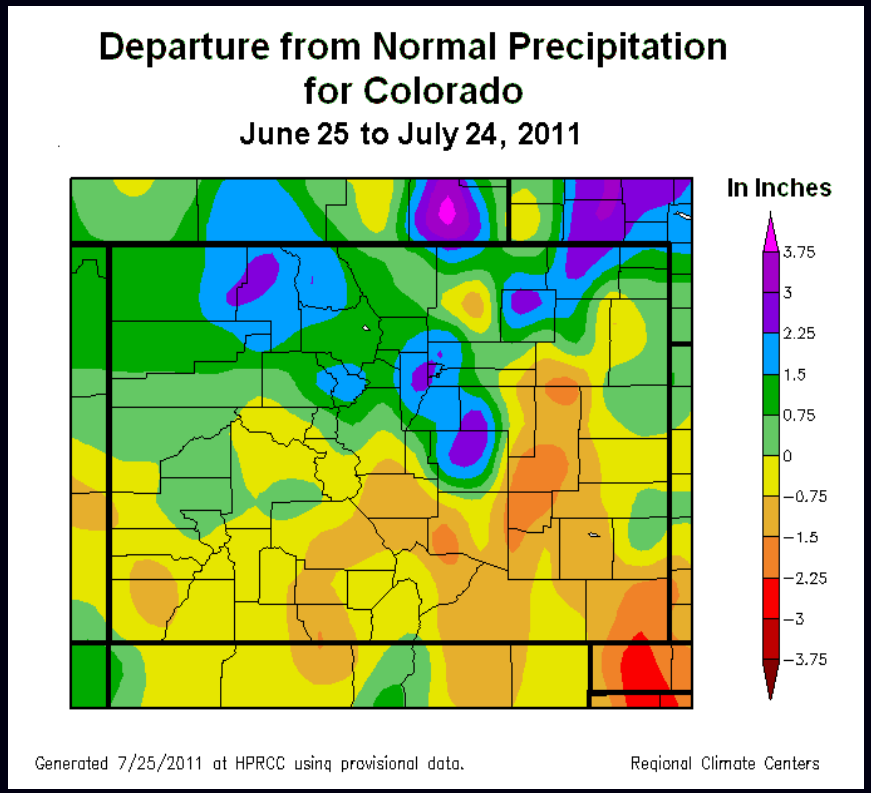
The passage of two shortwave troughs late on Monday and Tuesday also set the stage for very heavy rainfall across much of northeast Colorado.

This is a good example of monsoon pattern 1.

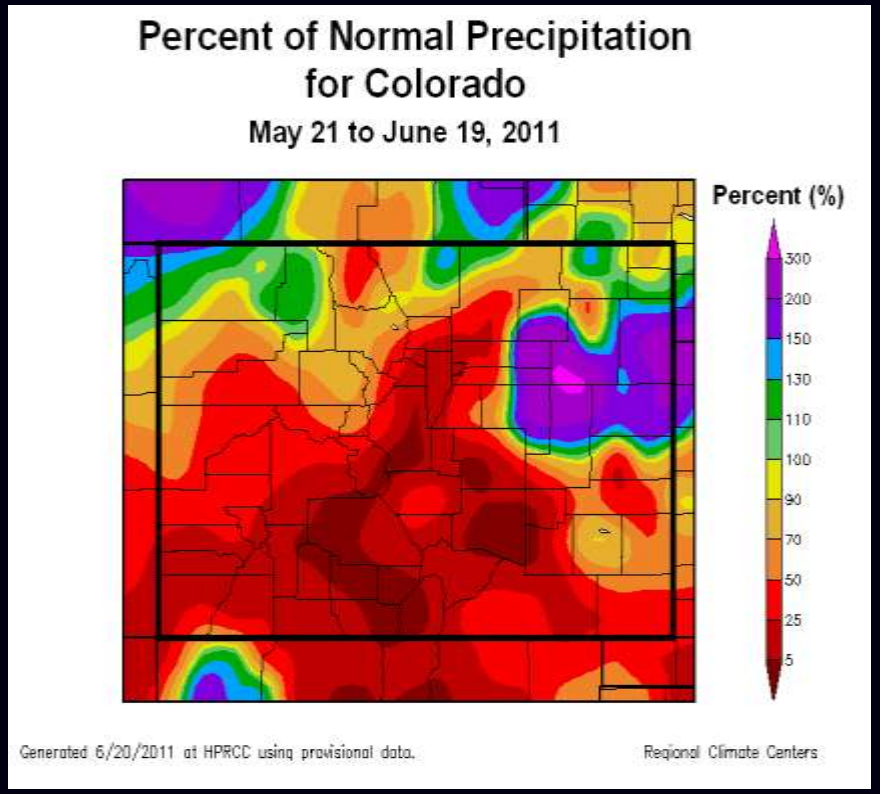


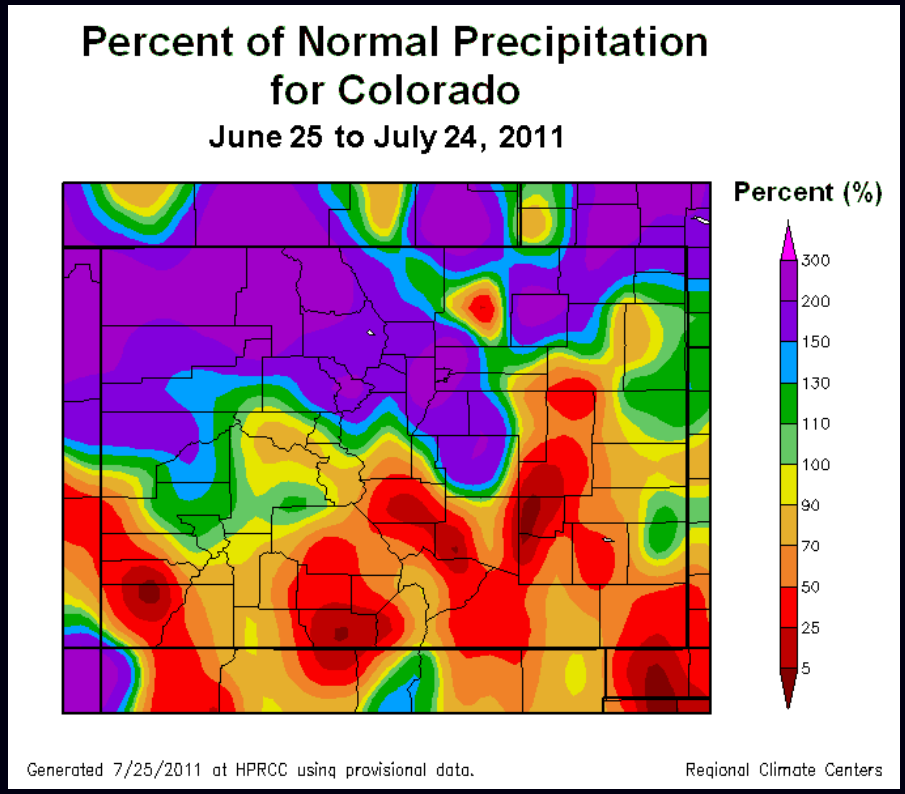
Impact of the Summer Monsoon on Temperature, Precipitation and Drought Conditions Across Colorado From Mid-June to Mid-July 2011



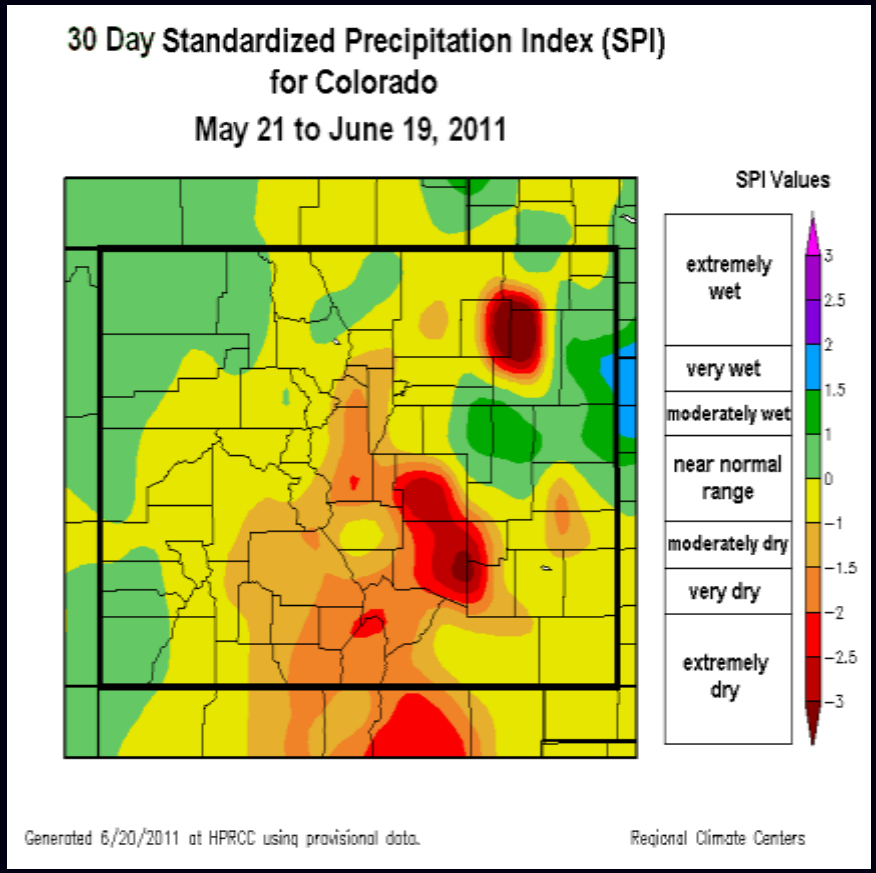


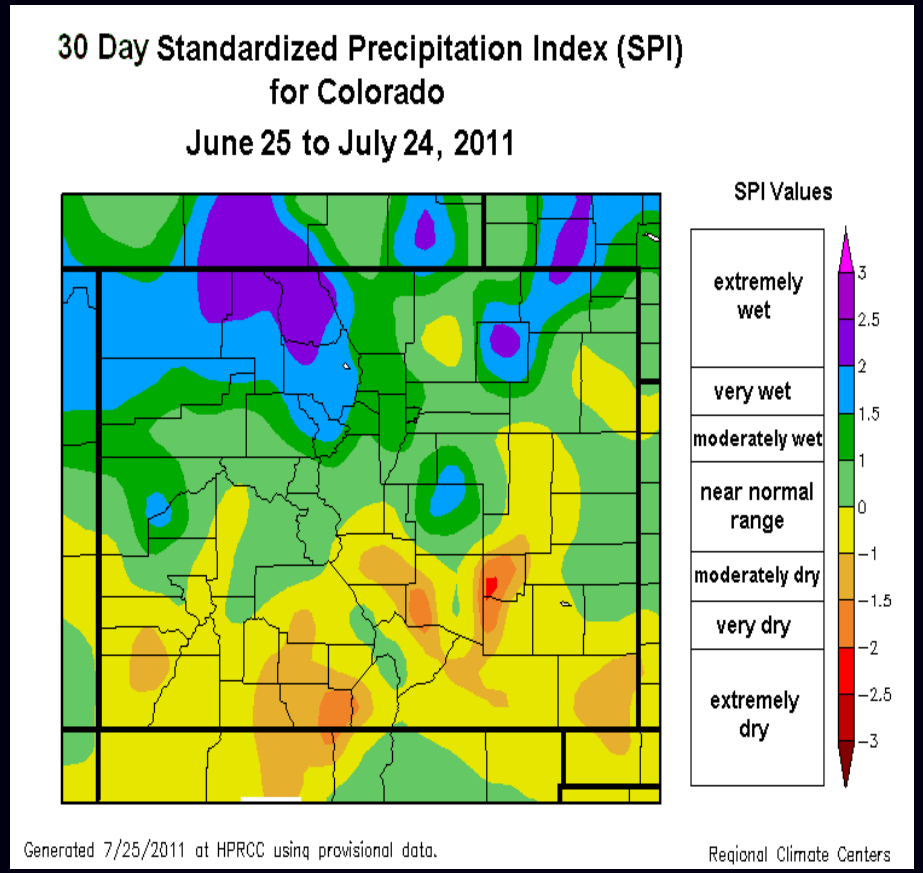
During the 30-day period ending June 19, 2011, precipitation across most of Colorado was below normal except on the northeast plains where totals were above 3.5 inches. Compare that to the 30-day period ending July 24th. Precipitation departures above normal increased across northern Colorado and most dramatically along the Front Range around the Denver area. Days of heavy rainfall from thunderstorms fed by a very moist monsoon moisture flow sent 30-day precipitation totals over 3 inches in the Denver area, on portions of the Palmer Divide southeast of Denver, and across the northeast corner of the state. Southern sections of the state saw relatively little change from the departures recorded during the previous 30-day period.



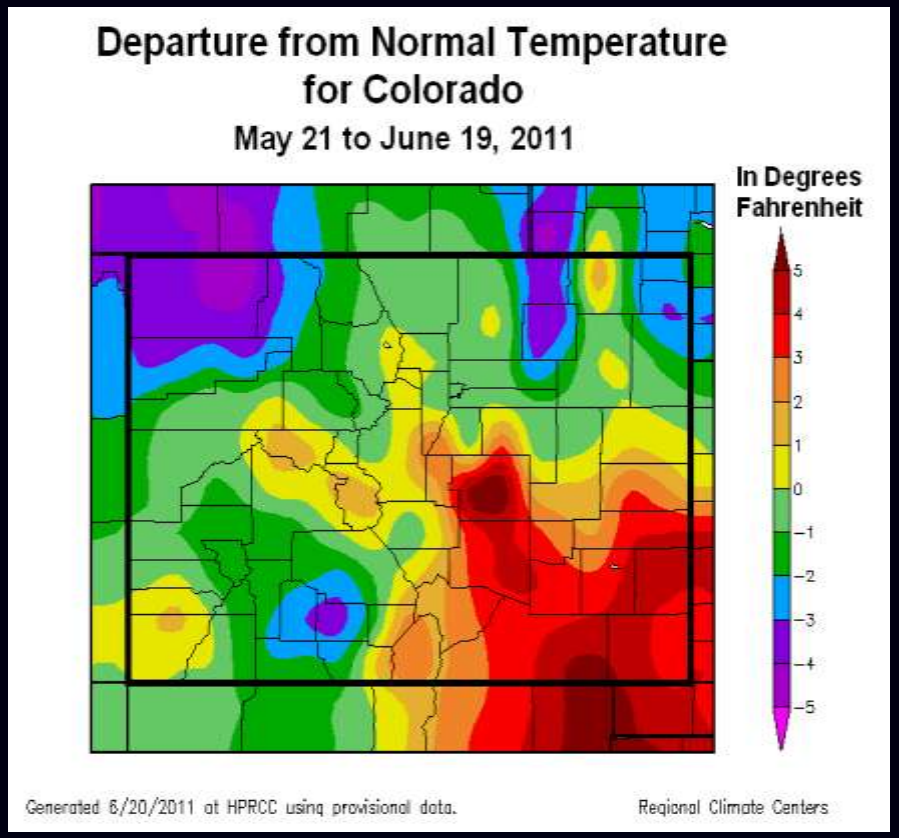


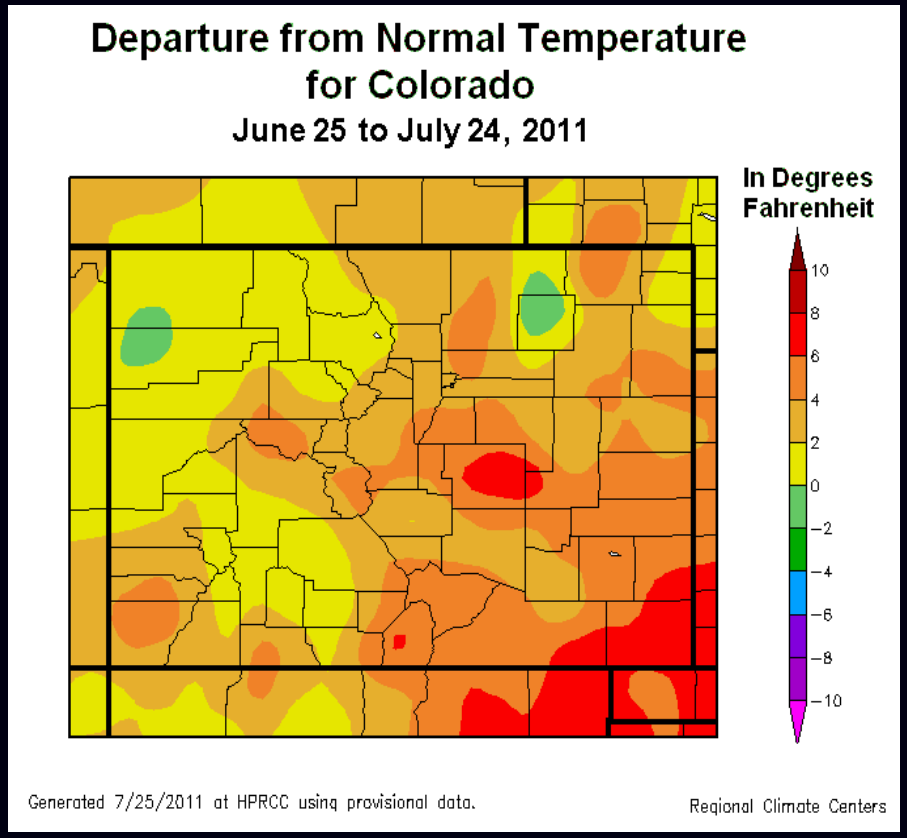
During the 30-day period ending June 19, 2011, precipitation across the southern two-thirds of Colorado was as much as 50 percent of normal. This included the northern I-25 urban corridor along the Front Range. Compare this to the 30-day period ending July 24th when most of this same area saw a surplus in precipitation. The most notable improvement in precipitation during this roughly 60–day period occurred in the southern and central mountains and in the vicinity of the Front Range around Denver. Precipitation during this period was as much as 300 percent above normal in and around Denver, attributable to heavy monsoon thunderstorms early in July.



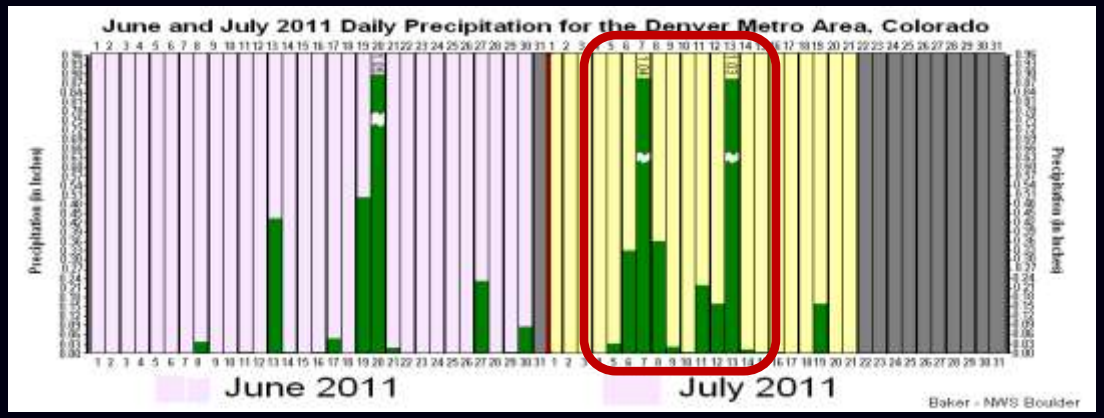


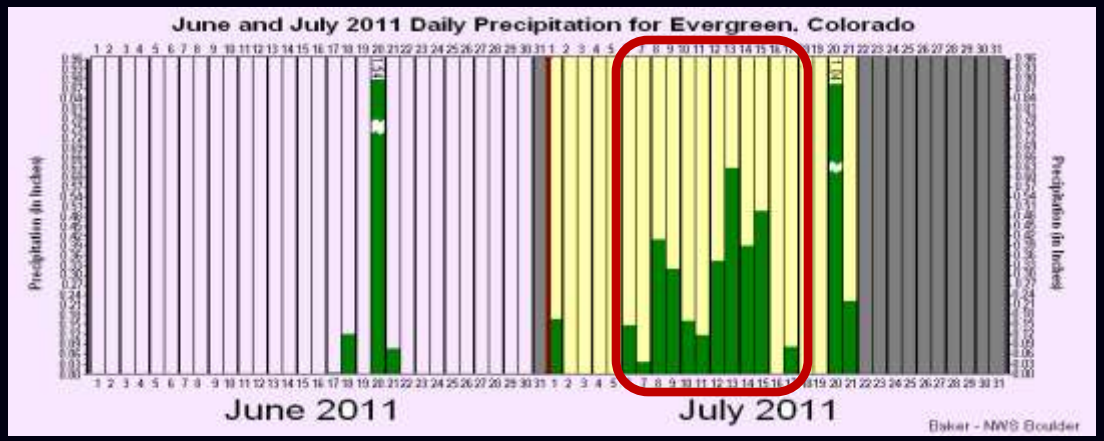
The Standardized Precipitation Index (SPI) also changed significantly across most of Colorado from the 30-day period ending June 19th and the 30-day period ending July 24th. Most notable change in the SPI occurred east of the mountains in the vicinity of Colorado Springs and in Morgan and Washington counties on the northeast plains where very wet to extremely wet conditions were indicated. Keep in mind that **SPI** was developed to monitor potential short term agricultural and long-term hydrological drought conditions, and that it is a probability index that considers only precipitation.

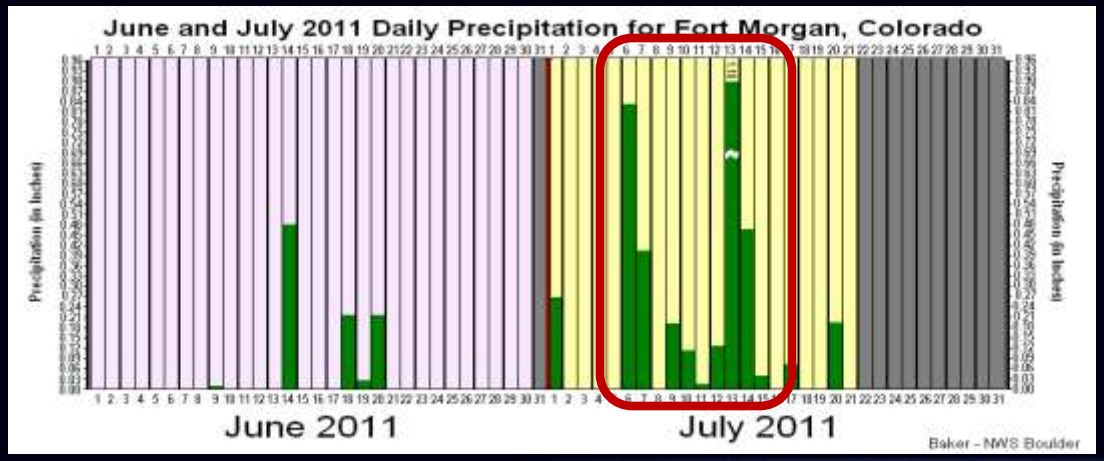




During the 30-day period ending June 19th, temperatures varied widely across Colorado from abnormally cool readings in the northwest to unseasonably warm temperatures across the southeast. This was not the case during the 30-day period ending July 24th. Temperature departures from normal eased across the west, while they increased uniformly in the mountains and east. A shift to a warm and moist southerly monsoon flow early in July caused temperatures to rise, particularly at night, due in part to an increase in the precipitable water vapor content (or humidity) of the atmosphere.





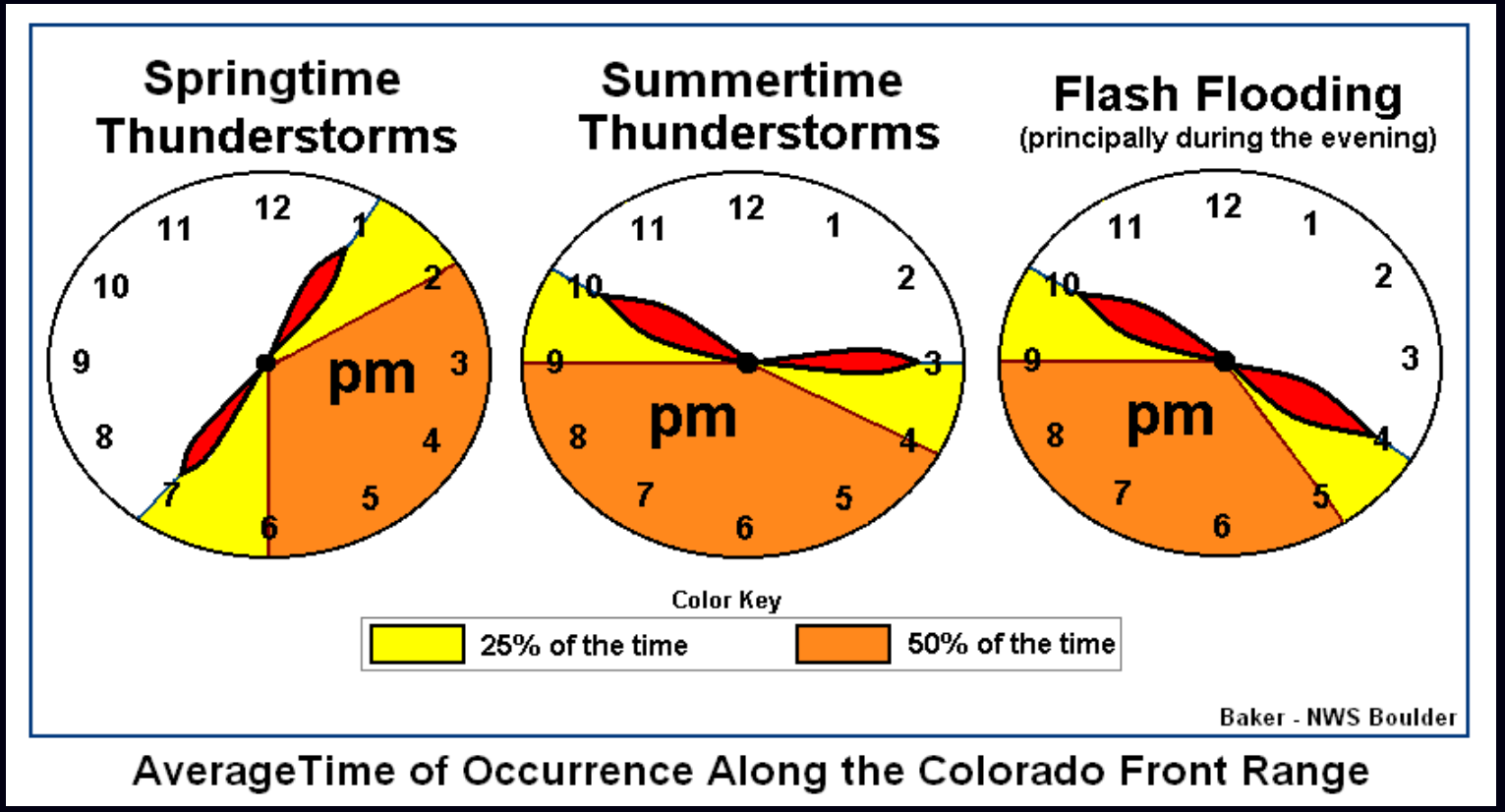


Daily precipitation data recorded at three locations along the Front Range in northeast Colorado from June 1 to July 21, 2011

This past June, precipitation in the Denver Metro Area, at Evergreen in the foothills southwest of Denver, and at Fort Morgan on the plains northeast of Denver, was confined mainly to a handful of days centered on the 19th of the month.

Essentially no precipitation fell at these locations during the last 8 days of June and the first 5 days of July; historically a period of low precipitation and hot temperatures along the Colorado Front Range.

On July 6th, the early arrival of the monsoon resulted in several straight days of measurable precipitation, at times quite heavy, in the Front Range and across northeast Colorado.



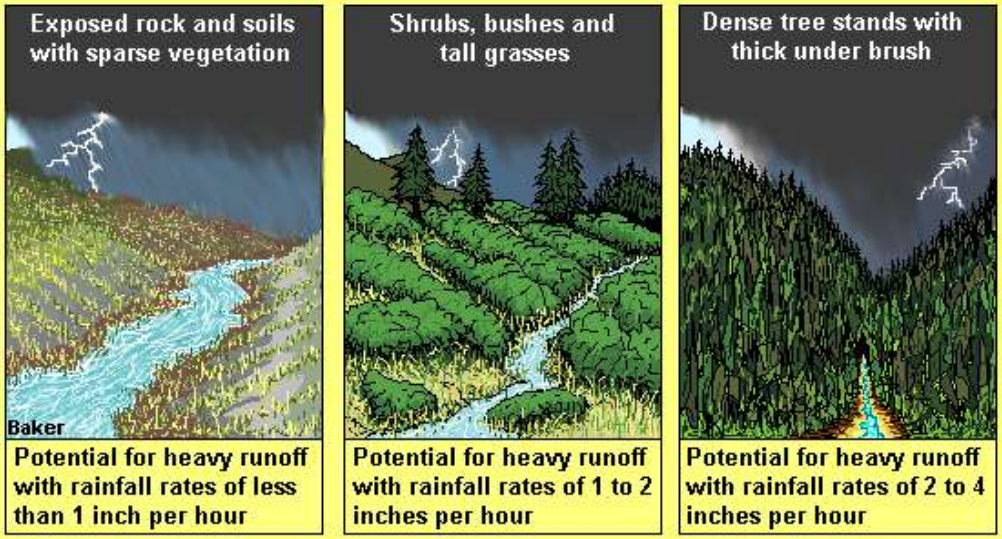
AverageTime of Occurrence Along the Colorado Front Range

During April, May and June, convection (i.e., thunderstorms) is more likely to occur along the Colorado Front Range in the afternoon. Storms normally form first over the sun drenched east-facing slopes of the Front Range in the late morning and early afternoon before moving east and/or forming new storms on the nearby plains during the afternoon (see left diagram.)

During July and August, particularly in the presence of the summer monsoon, thunderstorms along the Front Range tend to occur later in the day, and are more likely to persist well into the evening (see middle diagram.)

Thunderstorms, particularly those that form in the presence of moisture rich subtropical air (the monsoon) are more likely to produce heavy rainfall resulting in flash flooding. Due to lighter winds aloft in the summer, thunderstorms generally move slower, potentially lengthening the time that rain will fall on an area (see right diagram).

Influence of Slope and Vegetation on Rainfall Runoff

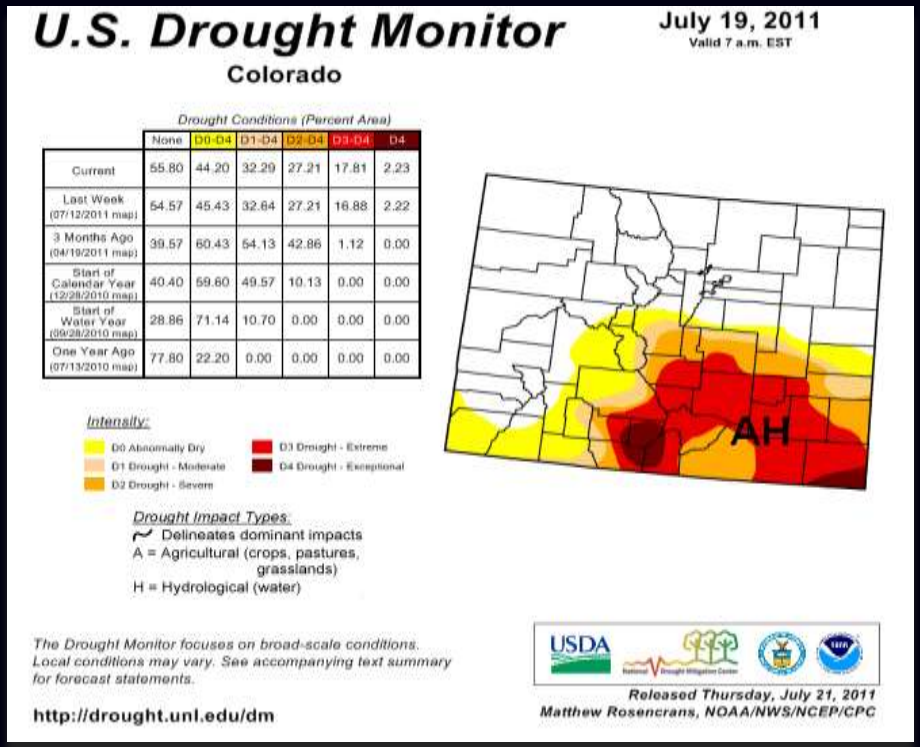


Baker - NWS Boulder

Many factors contribute to flash flooding. In addition to heavy rainfall over a relatively short duration, the type and amount of vegetation and the degree of slope of the ground are also major contributors to the flash flood equation. Sparsely vegetated slopes, particularly those recently denuded by a recent wildfire, are especially prone to flash flooding. The steeper the slope, the greater the risk of flash flooding. On the other hand, flat or gently sloped ground heavily covered with vegetation are least likely to flash flood, even with very heavy rainfall.

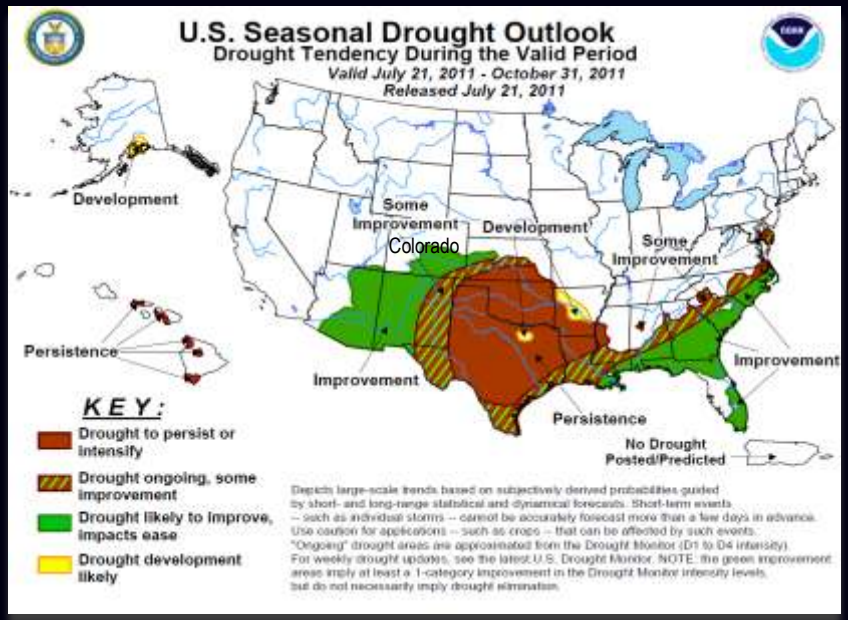
Even on a clear day along the Colorado front range, the risk of flash flooding may be only hours away. One should ***never*** ignore the possibility of ***flash flooding***, particularly in steep mountainous terrain and in areas recently burned over by wildfire.

Recent Drought Conditions and Outlook for Colorado



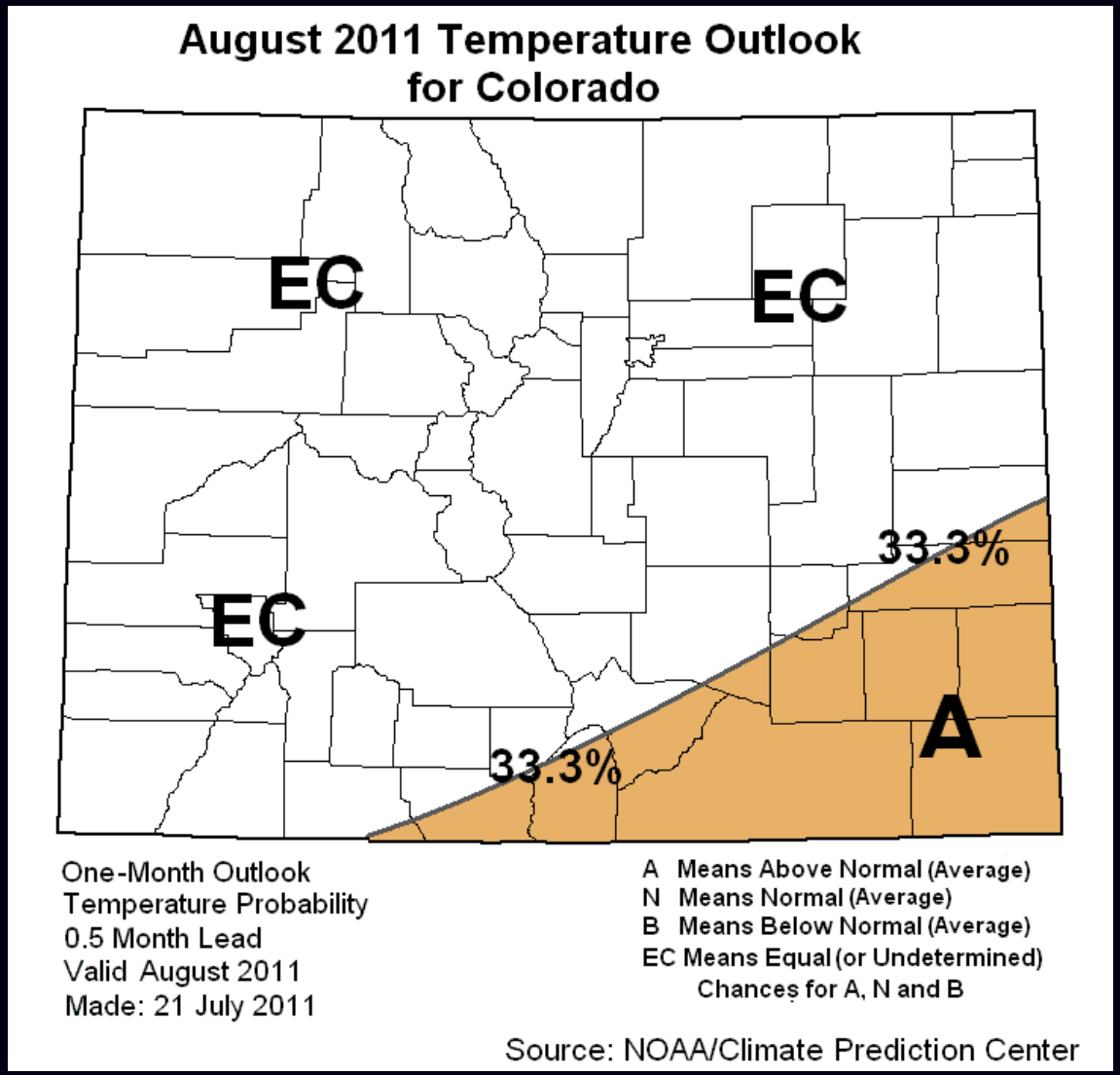
As of the middle of July, drought was principally confined to the south central mountains and valleys, the southeast plains and the extreme southwest corner of Colorado. According to the July 19, 2011 issue of the U.S Drought Monitor, exceptionally dry conditions still exist on the far southeast plains and in the San Luis Valley of south central Colorado.

In recent weeks, drought conditions have eased across Colorado, due in large part to the enhanced thunderstorm activity associated with the summer monsoon. Not all areas benefitted from these storms, but those areas that did, such as northeast Colorado, saw a marked improvement. The latest U.S. Seasonal Drought Outlook calls for likely improvement in the drought conditions across southeast Colorado in the months to come.



Source: National Drought Mitigation Center

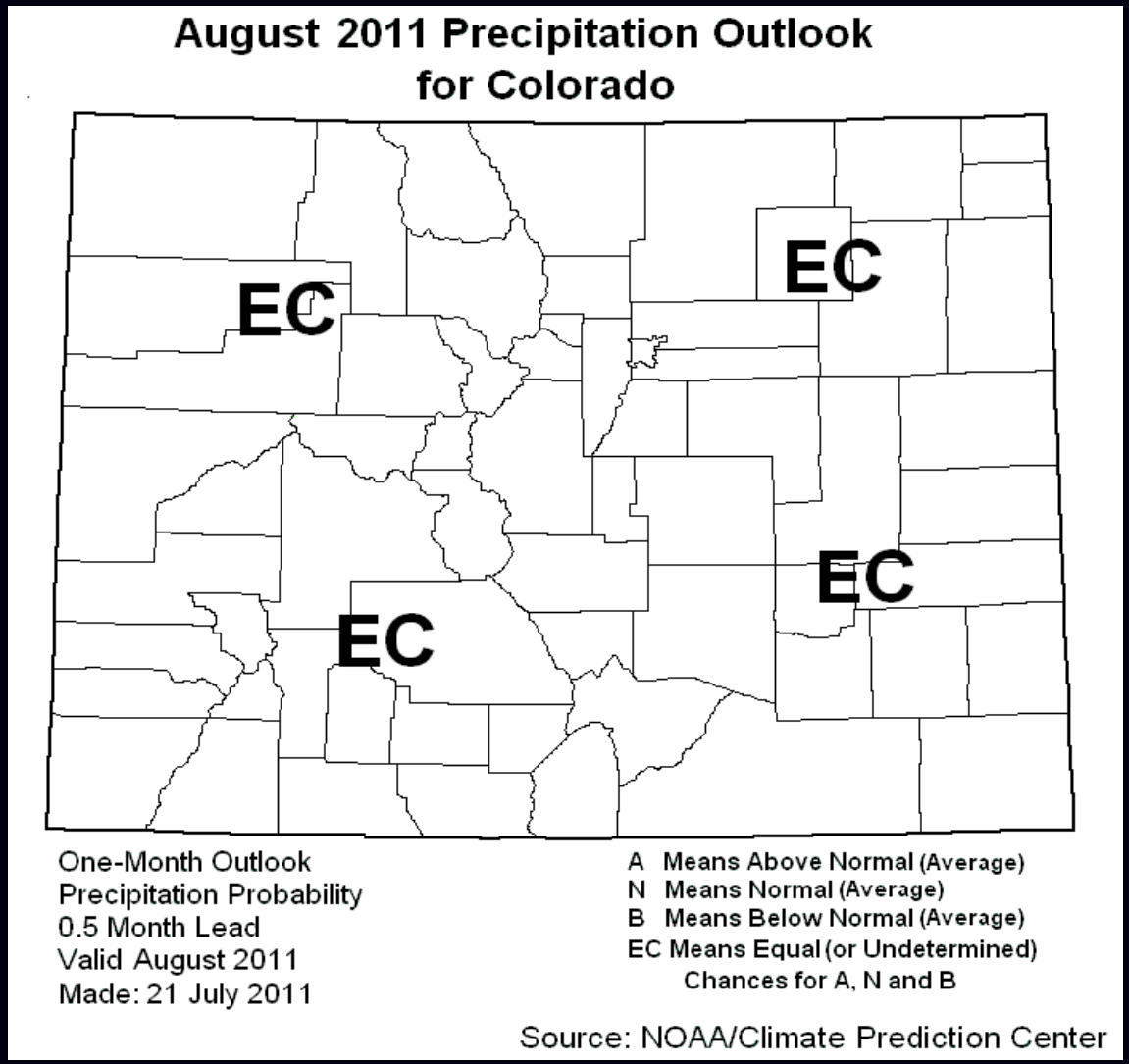
August - October 2011
Temperature and Precipitation
Outlooks and Composites
for Colorado
From NOAA's
Climate Prediction Center



August 2011 Temperature Outlook For Colorado

The August temperature outlook from the Climate Prediction Center (CPC) calls for at least a 33 percent chance for above average temperature across the southeast corner of Colorado.

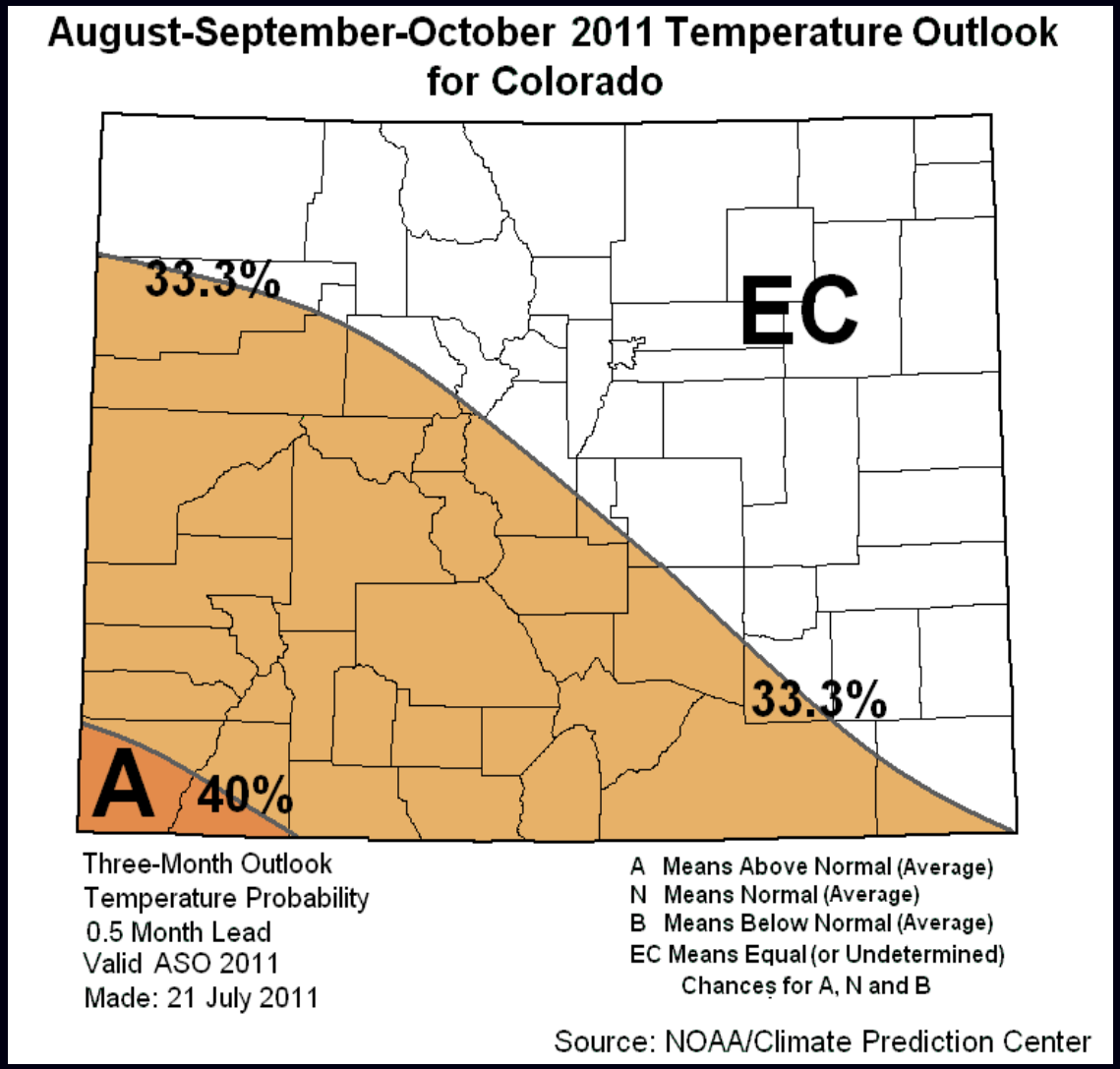
The outlook is less certain for the remainder of the state as indicated by the EC designation.



August 2011 Precipitation Outlook For Colorado

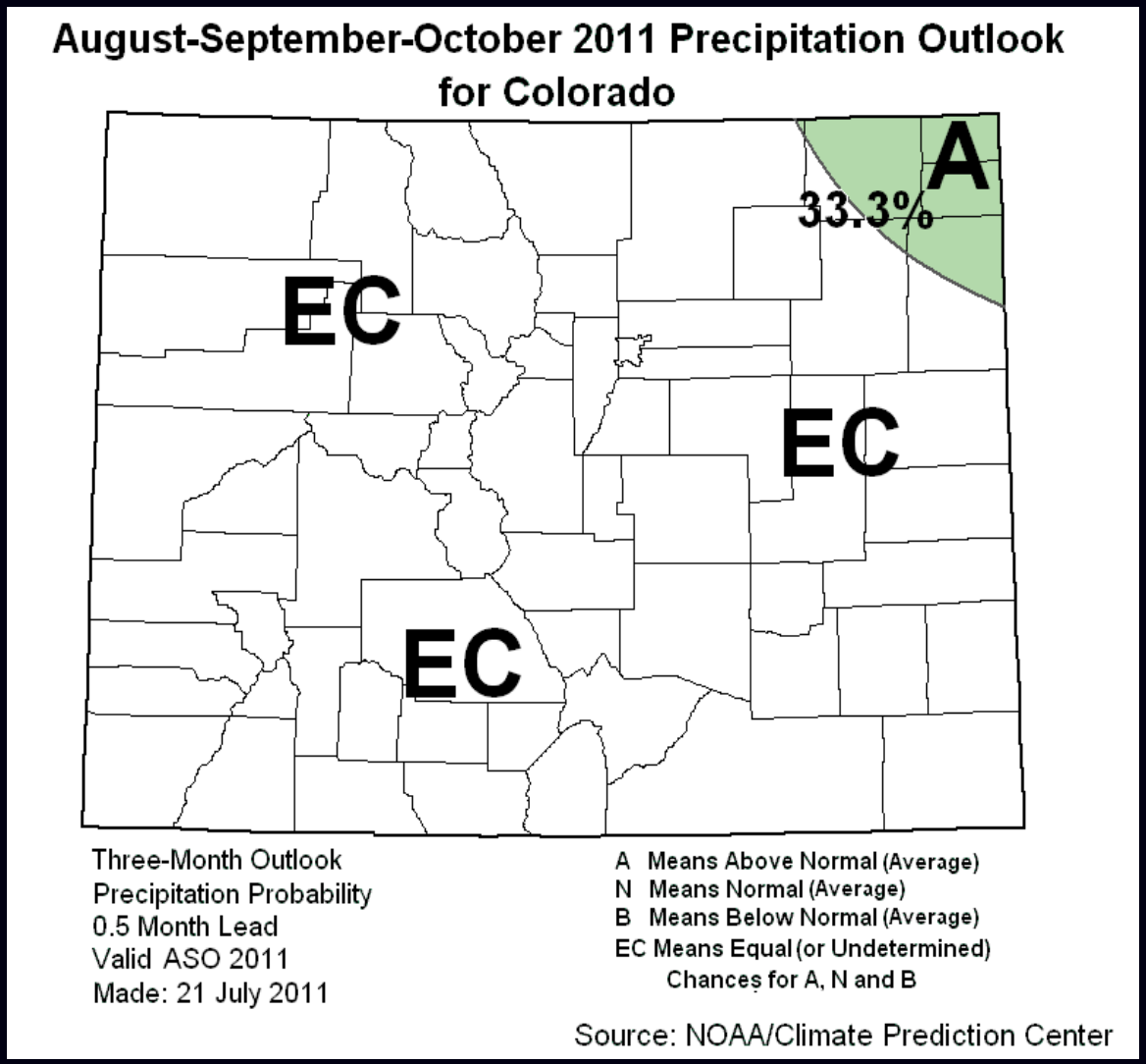
The August precipitation outlook from CPC calls for an equal or undeterminable chance for above, below and normal (average) precipitation, as indicated by the EC designation.

August, September and October 2011 Temperature Outlook for Colorado



The latest CPC outlook calls for better than a 33 percent chance for above average temperature across roughly the southwest one-half of Colorado and at least a 40 percent chance for above average temperature in the extreme southwest corner of the state.

The outlook for the rest of Colorado is less certain, with an equal of undeterminable chance for above, below and average temperatures as designated by the EC symbol.

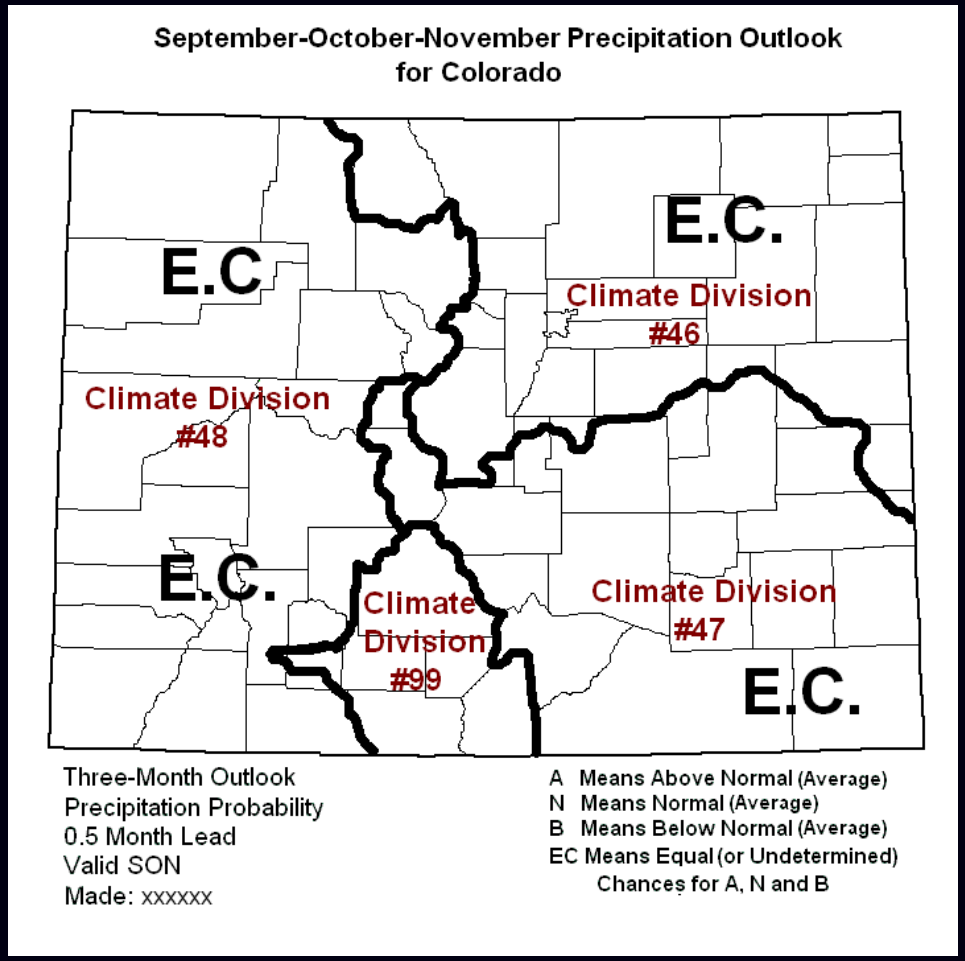


August, September and October 2011 Precipitation Outlook for Colorado

The latest CPC outlook calls for at least a 33 percent chance for above normal (average) precipitation across the far northeast corner of Colorado during the period.

For the remainder of the state, the outlook is less certain, as indicated by the EC symbols.

Adding Value to An "EC" Outlook from CPC



Climate outlooks issued by the Climate Prediction Center (CPC) will often indicate an equal or undeterminable (EC) chance for above, below and average temperature or precipitation outlook for a region. An EC outlook by itself provides little indication for a particular trend in temperature and precipitation for a given season.

However, to add some value to an "EC" outlook, one can refer to temperature and precipitation composites prepared by CPC for every climate division in the United States. These composites provide the user with a historical perspective of how temperatures and precipitation have trended during El Niño, ENSO-neutral and La Niña conditions.

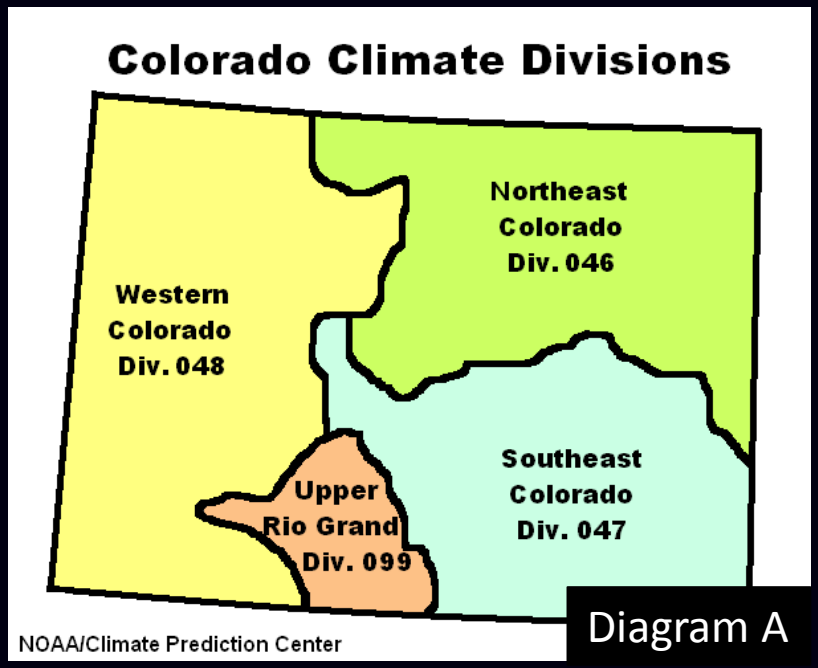


Diagram A

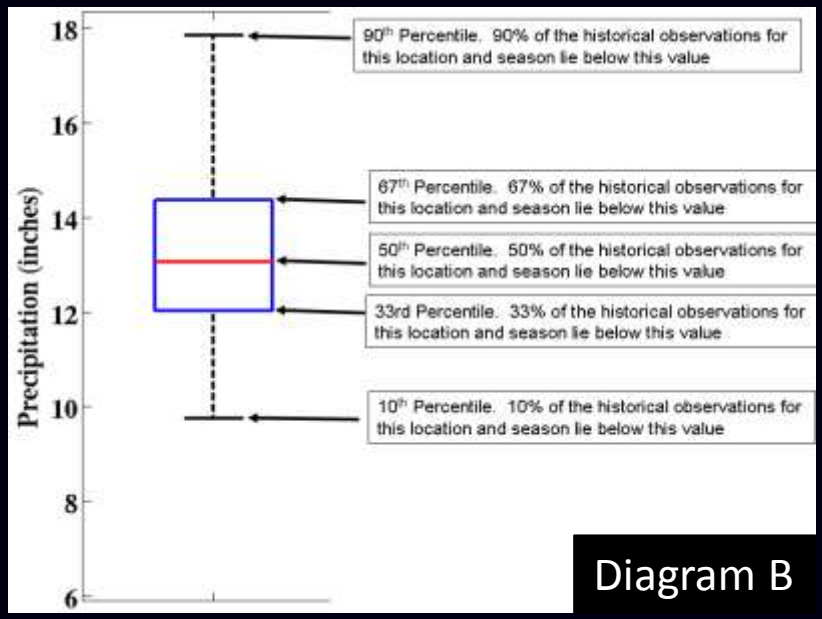


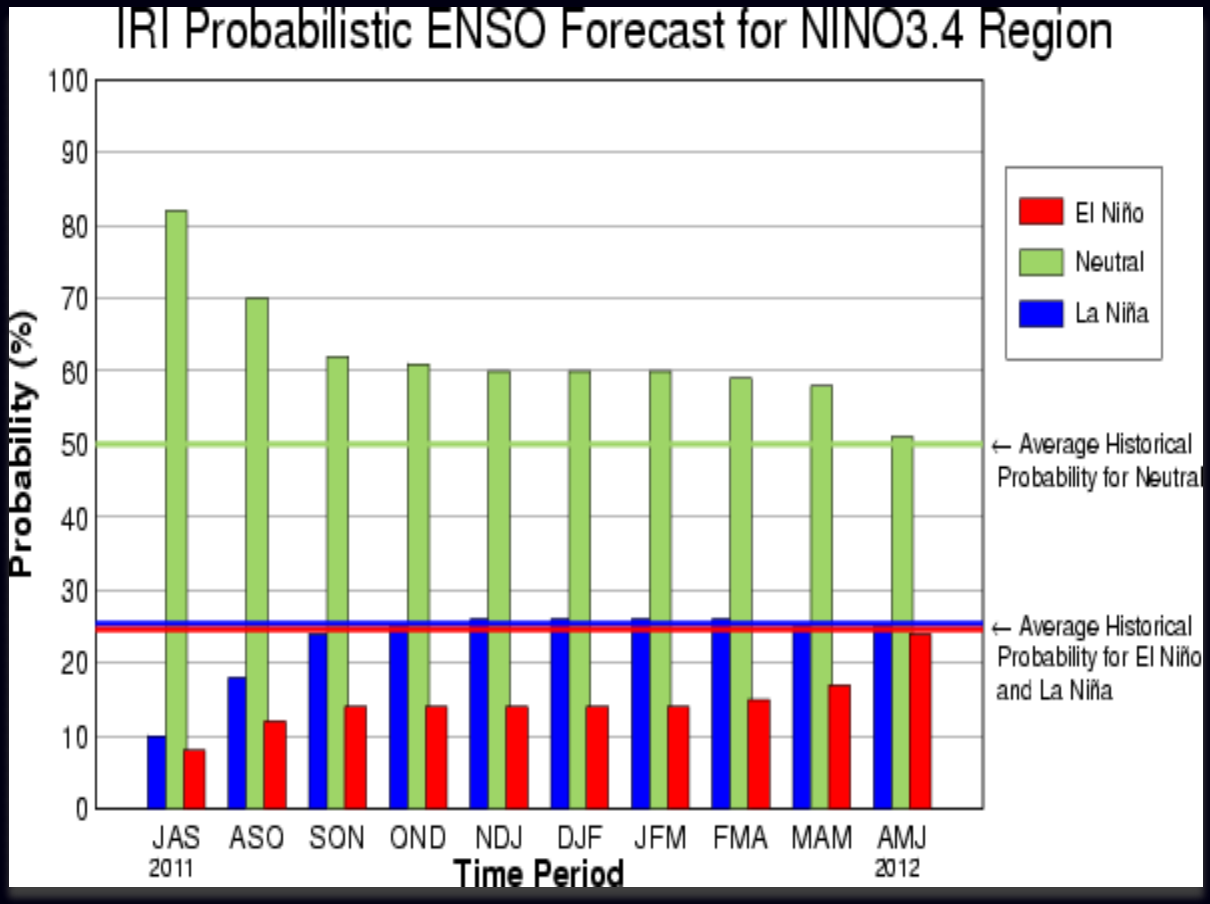
Diagram B

Diagram A: Colorado is sub-divided into four climate divisions. Climate divisions 046, 047 and 099 are located east of the Continental Divide, and division 048 west of the Divide.

NOAA's Climate Prediction Center (CPC) has produced historical distributions of 3-month temperature and precipitation associated with three different ENSO categories – El Niño, La Niña and neutral (non-ENSO) events – for each of climate division.

Diagram B: These historical temperature and precipitation distributions can be viewed using an ENSO box and whisker analysis plot (explanation to the left).

The red line inside the ENSO box represents the mean or 50th percentile of the data (temperature or precipitation) distribution. Approximately 34% of the total observations exist within the ENSO box, and the remaining observations (or 66%) outside of the box.



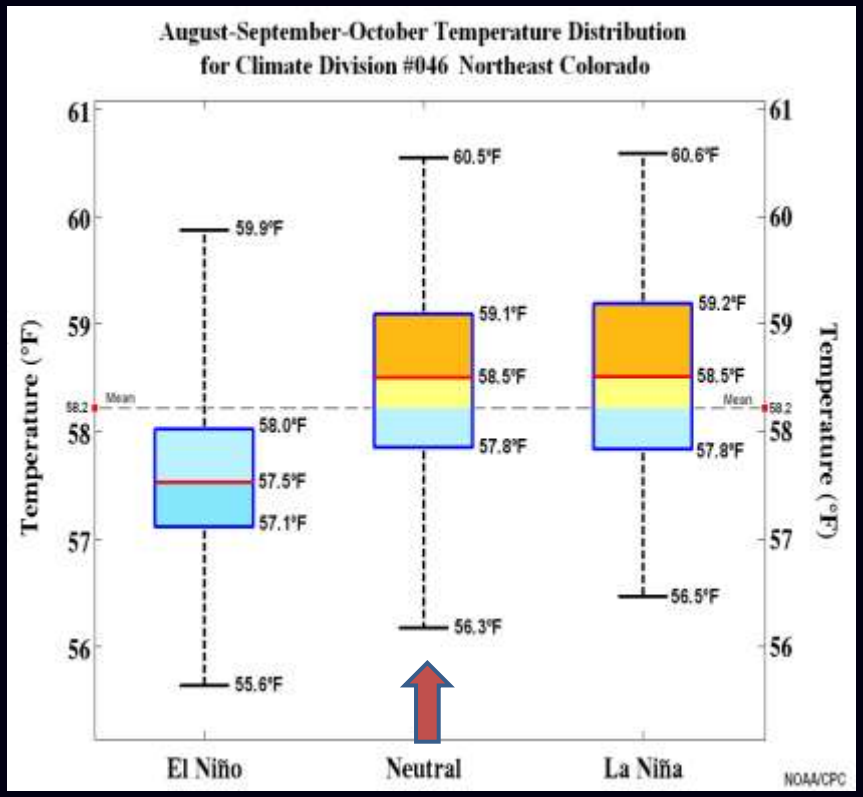
Source: International Research Institute for Climate and Society (IRI) – Updated 7/21/11

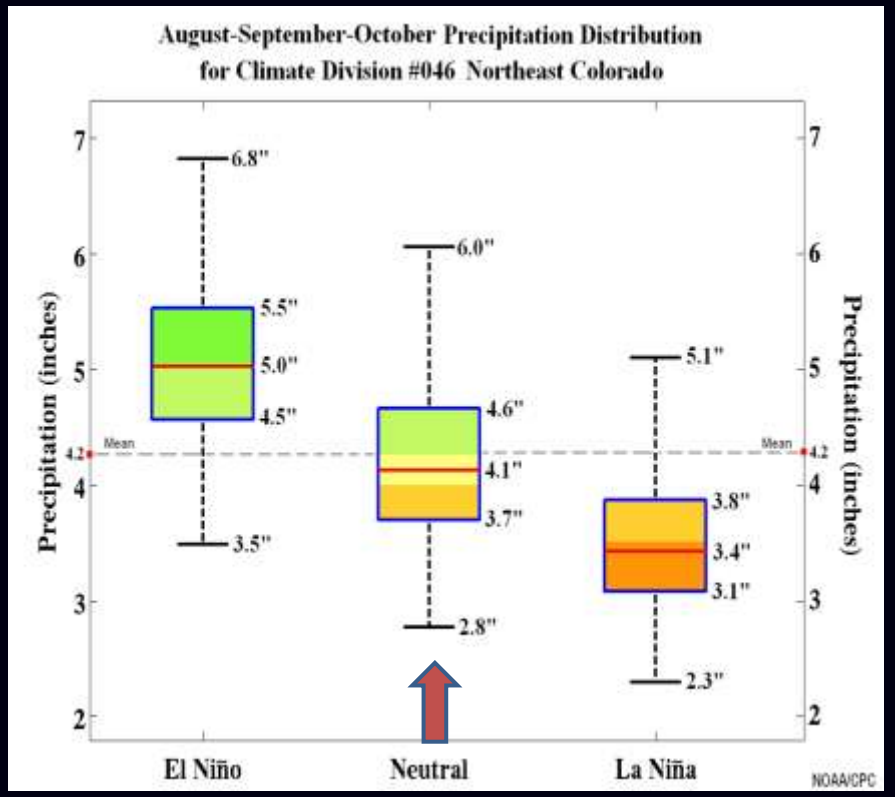
Before proceeding to the final slides…

recall that the latest probabilistic ENSO forecast is for ENSO-neutral conditions this fall and winter.

However, the forecast for ENSO beyond this summer remains uncertain due to lower model forecast skill out that far.

ENSO Box and Whisker Analysis Plots for the Northeast Colorado Climate Division #046 for the 3-Month Season August-September-October

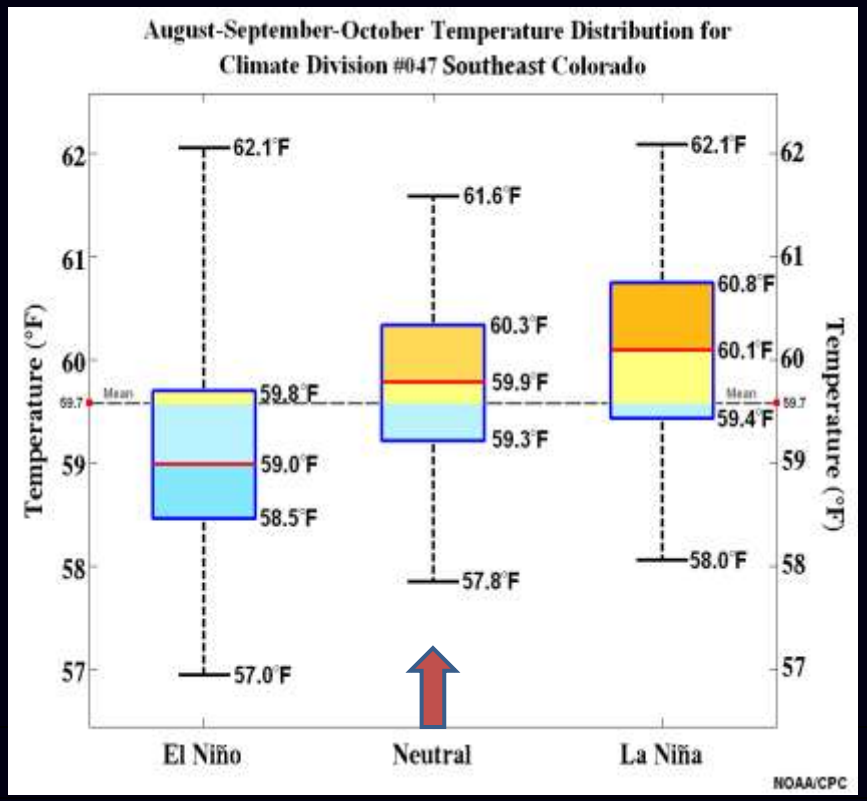




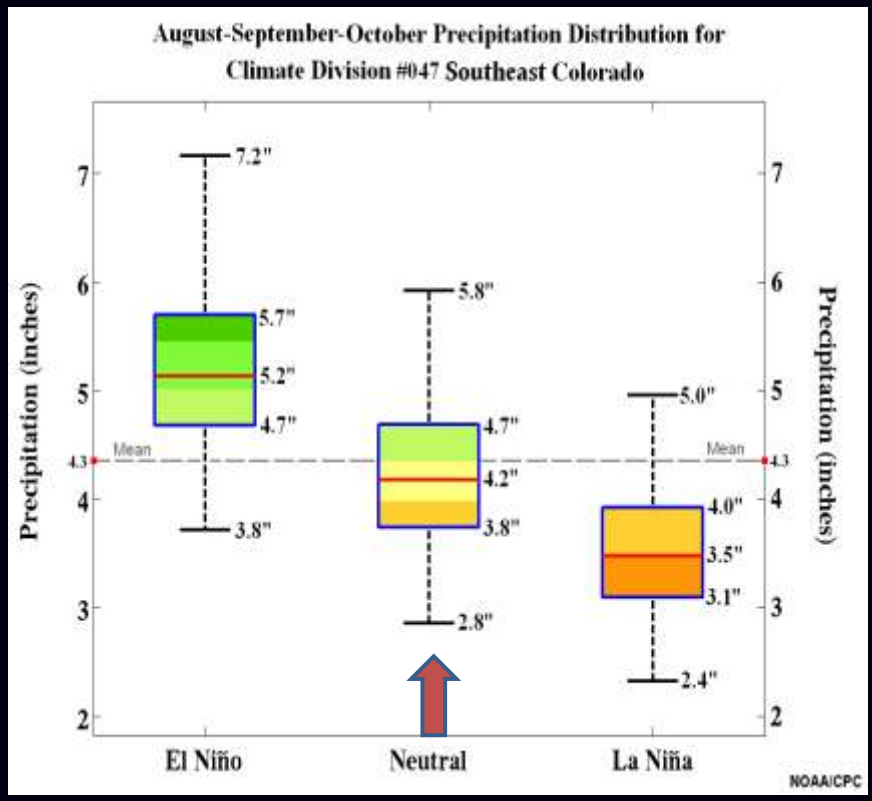
According to composites prepared by the Climate Prediction Center, temperature in northeast Colorado was slightly above average during ENSO-neutral and La Niña conditions and, below average during El Niño conditions for the three month period of August, September and October.

Historically, precipitation in northeast Colorado was above average during El Niño conditions, near average with ENSO-neutral conditions, and below average with La Niña conditions during the same three month period.

ENSO Box and Whisker Analysis Plots for the Southeast Colorado Climate Division #047 for the 3-Month Season of August-September-October

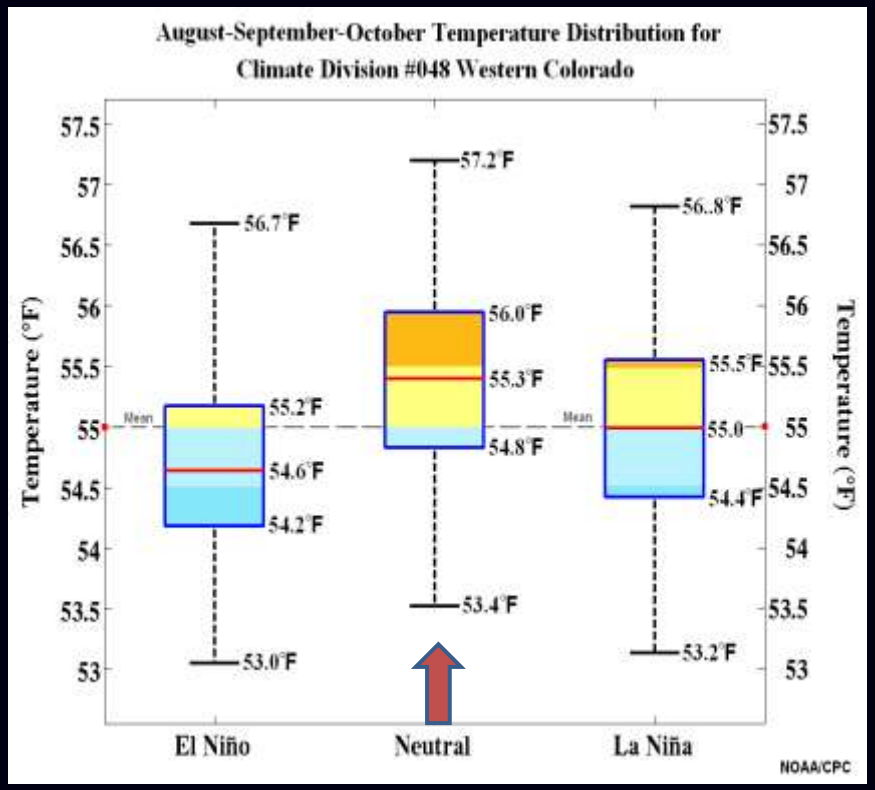


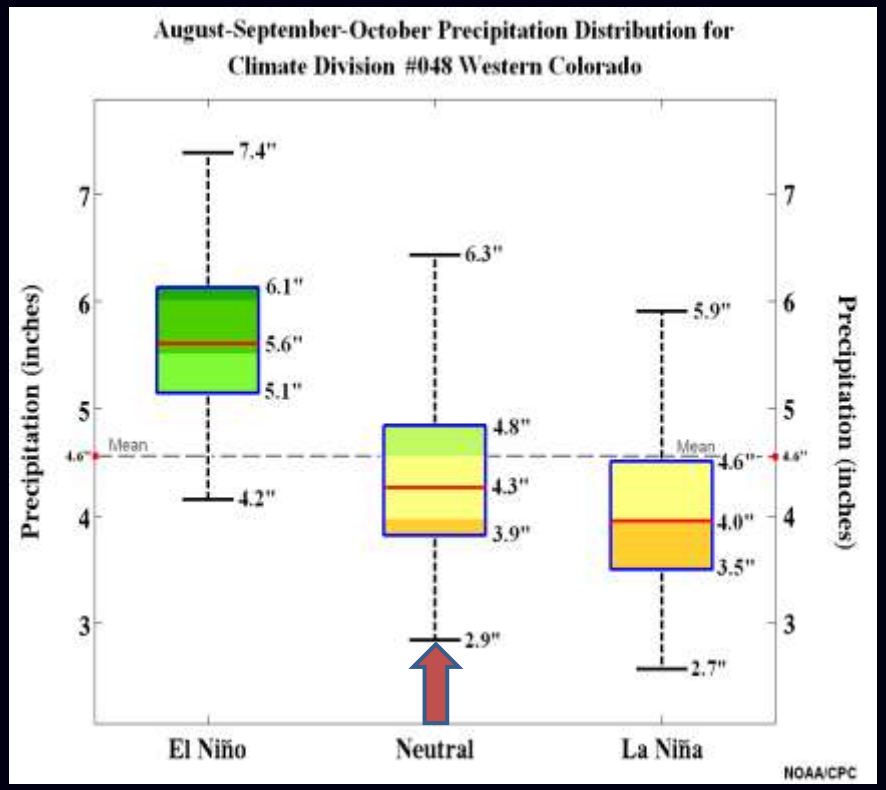
Historically, temperature in southeast Colorado was slightly below average during El Niño conditions, near average with ENSO-neutral conditions, and slightly above average during La Niña conditions for this three month period.



Precipitation in southeast Colorado was above average during El Niño conditions, near average with ENSO-neutral conditions and below average during La Niña conditions for this period.

ENSO Box and Whisker Analysis Plots for the Western Colorado Climate Division #048 for the 3-Month Season of August-September-October





For western Colorado, temperature was slightly below average during El Niño conditions, slightly above average with ENSO-neutral conditions, and average during La Niña conditions for this three month period.

Historically, precipitation in western Colorado was above average during El Niño conditions, slightly below average with ENSO-neutral conditions, and below average during La Niña conditions for this period.